NASA ONLY

C.N.: G. Young 4211
T.R. J. J. Parker, 735

REPORT NO. GDC-ZZL 68-001

CR# 95619

FINAL REPORT
THE REFINEMENT OF GRAVITY GRADIENT BOOMS AND DEPLOYERS

CONTRACT NO. NAS 5-10376

Prepared by
CONVAIR DIVISION OF GENERAL DYNAMICS
San Diego, California
for
GODDARD SPACE FLIGHT CENTER
Greenbelt, Maryland

GENERAL DYNAMICS
Convair Division

+ GDC

REPORT NO. GDC-ZZL68-001

FINAL REPORT

THE REFINEMENT OF GRAVITY GRADIENT BOOMS AND DEPLOYERS

CONTRACT NO. NAS 5-10376

1 February 1968

Prepared by
CONVAIR DIVISION OF GENERAL DYNAMICS
San Diego, California
for
GODDARD SPACE FLIGHT CENTER
Greenbelt, Maryland

SUMMARY

This final report was prepared under authority of Contract NAS5-10376, The Refinement of Gravity Gradient Booms and Deployers, conducted by Convair division of General Dynamics, H. R. Wiant, Project Leader. The object of this program, as a follow-on to Contract NAS5-9597, Gravity Gradient Boom and Antenna Material Study, was to provide longer wire screen booms, develop a boom joining technique, and provide improved deployers. This was accomplished in three concurrent phases, in which 1) three 150-foot wire screen booms were formed, 2) two boom joining techniques were developed, and 3) improved deployment mechanisms were designed and fabricated. Three 150-foot booms, two deployment mechanisms, and three splice test specimens were delivered under the terms of the contract.

The wire screen boom configuration was optimized to an Elgiloy 16 mesh by 0.0081-inch-diameter longitudinal wire with a Copper-Beryllium Alloy 25 18 mesh by 0.0070-inch-diameter circumferential wire. Booms were fabricated to a three-quarter inch diameter, 150 feet long. Limited testing and evaluation showed that the booms were well within the desired limits of straightness and thermal deflection. Joining techniques for splicing were developed which had no effect upon any of the critical properties of the boom. This assures the potential use of this boom type in any unlimited length.

An engineering prototype deployer was redesigned and improved during the program. A 45 percent weight reduction was achieved and construction details improved such that the deployer passed the pertinent tests of Specification S2-0102, ATS satellite.

This program further proved the basic concept of the wire screen boom. Inherent boom straightness, both from a manufacturing and use aspect, have been shown. Further modifications to the wire screen configuration could reduce the present limit of 3/4-inch boom diameter to as low as 1/2 inch and thus be instrumental in reducing the low thermal distortion values even lower. Reduction in the size and weight of the deployer would also be accomplished with the smaller boom.

The Convair division of General Dynamics identification number for this report is GDC-ZZL68-001.

ACKNOWLEDGEMENTS

The Refinement of Gravity Gradient Booms and Deployers, Contract NAS5-10376, was conducted at Convair division of General Dynamics in the Materials and Process Department, Process Development Group, with Mr. A Hurlich, manager and Mr. M. D. Weisinger, group engineer, respectively. Mr. H. R. Wiant was project leader and responsible for the boom process development and hardware. Mr. B. Turovlin conducted the redesign studies on the deployment mechanism. Mr. G. Sawyer and N. Kinnischtzke were program technicians. Mr. E. W. Wrench acted as consultant throughout the program.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

GLOSSARY OF WIRE CLOTH TERMS

COUNT	Number of open spaces per lineal inch.
CRIMP	Undulations in warp and fill wires which lock all wires in position. Sometimes called double crimp because both warp and fill wires are crimped.
FILL WIRE	Wire running transversely through the screen. Also called the shute wire.
MESH	Number of openings per lineal inch, measured from the center of any wire. See rectangular mesh and square mesh.
OFF-COUNT MESH	Rectangular mesh.
RECTANGULAR MESH	Mesh count greater in one direction than in the other. Sometimes called off-count mesh.
ROLL	The standard method of packing wire screen. A standard roll contains 100 lineal feet.
SELVAGE	The finished woven edge of wire screen.
SHUTE WIRE	Wire running transversely through the screen. Also called fill wire.
SPACE	Size of the clear opening between parallel adjacent wires.
SQUARE MESH	Mesh count identical in both directions.
WARP WIRE	Wire running parallel to the length of the screen.
WEAVE	The manner in which warp and fill wires are interwoven. Plain weave screen has each warp wire passing alternately over and under the fill wires at right angles.

DEFINITIONS

D	Boom diameter	in.
D_c	Circumferential wire diameter	in.
D_l	Longitudinal wire diameter	in.
K	Thermal conductivity of the circumferential wires	$\frac{Btu}{hr\text{-}ft\text{-}°R}$
M_c	Circumferential wire mesh size	$\frac{wires}{in.}$
M_l	Longitudinal wire mesh size	$\frac{wires}{in.}$
Q_s	Solar constant	$\frac{Btu}{hr\text{-}ft^2}$
T	Temperature	°R
α	Absorptance	

SECTION 1

INTRODUCTION

This report presents in detail the history and results of the Refinement of Gravity Gradient Booms and Deployers, conducted under Contract NAS5-10376. The broad objective of the program was the refinement of the rigidized, woven-screen gravity gradient boom and the deployer previously developed under Contract NAS5-9597. This follow-on program was intended to provide longer booms, develop a boom joining technique, and provide improved deployers.

The work statement from Contract NAS5-10376 has been reprinted in this report as Appendix I for reference to scope, materials, constraints, and limitations.

The dual-material, woven-screen gravity gradient boom was developed under Contract NAS5-9597. Three Elgiloy-copper beryllium screens with different percent open-areas were rigidized by brazing and formed into 45-foot booms of a nominal diameter of 3/4 inch. Processes were developed to permit continuous fabrication of booms. A theoretical thermodynamic analysis of the screen-type boom was conducted and used as a basis for the practical application. An engineering prototype deployment mechanism was designed, fabricated, and tested to prove the feasibility of deployment and reroll of the rigidized screen boom. A limited testing and evaluation phase was conducted to determine the general characteristics of the low-distortion screen boom concept.

The wire screen boom concept proved to be a highly practical approach to the development of a low thermal distortion boom for space application. The complex nature of a rigidized, woven, dual-material screen boom precluded analytical stress analysis, but selected physical parameters produced booms well within the envelope of usability. The thermal analysis of uncoated wire booms was used as a basis for final fabrication of booms and proved highly adequate. The entire analysis and computer program were presented in full detail. The testing phase, although limited in extent, showed the wire screen boom to be uniform and reliable. The engineering prototype deployer was simple, direct, and reliable. The basic design was developed as potential space hardware.

The following summary of work performed under Contract NAS5-10376 is presented in the order of the three phases presented in the work statement (Appendix I), i.e., Boom Development, Boom Joining, and Deployment Mechanism. Work was conducted on all three phases throughout the entire program. A complete screen boom processing procedure is included in Appendix II, and a splicing procedure is described in Appendix III.

†For further details on the early development of screen boom material refer to: "Final Report for Gravity Gradient Boom and Antenna Material Study," prepared by Convair division of General Dynamics for Goddard Space Flight Center, Greenbelt, Maryland, 18 August 1967.

SECTION 2

DISCUSSION

This section presents the development and modification of boom production processes to permit the manufacture of booms of extended lengths from Elgiloy-copper beryllium wire screen. It describes the new equipment developed and the equipment modifications required to perform the task. The results of tests on the finished booms are presented and analyzed. Development of splicing techniques is described and the results of the tests performed on spliced booms are given. This section also includes a detailed description of the improved deployment mechanism developed, constructed, and delivered under the contract.

2.1 BOOM DEVELOPMENT

Process modifications for the making of extended-length booms were required throughout. In some cases, the modifications were relatively minor and required only refinements of existing equipment. In other areas, new and different equipment had to be built or purchased and modified for the task. New wire screen material had to be purchased to comply with the 150-foot length requirement and an analysis was conducted to determine an improved mesh and wire configuration. The boom fabrication technique was successfully modified to fully meet and exceed the contract requirements as demonstrated by the actual fabrication of one continuous boom length of 341 feet.

2.1.1 WIRE SCREEN SELECTION AND WEAVING

The "optimum" wire screen boom produced under Contract NAS5-9597 did not fully meet the desired goals of bending strength and total stability. Analysis revealed the following primary inadequacies:

a. The circumferential mesh size, M_c, was changed from 20 to 16.5 through application of 20 percent stretch, which was added to the processing after the mesh had been established for expected strength levels.

b. Compressive failures were observed in the longitudinal wires as the primary failure mode.

c. The diameter of the circumferential wire, D_c, of 0.008 inch was too large for the basic boom diameter, D, of 0.75 inch, resulting in some yielding when the boom was flattened.

d. The resultant overall mesh size was not at a calculated minimum for temperature difference.

e. Yielding of the outer edge wires during final processing was observed.

Based on these factors and the measured values for bending moment and open areas, as well as past experience with six actual mesh sizes, a paper analysis was conducted to ascertain an improved single screen configuration.

The previous analysis indicated that to improve the performance of the screen booms, D_c must be made smaller, M_c should be increased, D_l (diameter of longitudinal wire) is influenced by M_l (longitudinal mesh size) which should be increased, and D preferably should remain constant. The following basis parameters were used to calculate boom temperature difference, ΔT, as presented in the computer program developed under Contract NAS5-9597.

Q_s	-	450 Btu/hr-ft^2
K	-	44 Btu/hr-ft-°R
T_{ref}	-	500°R
α_S	-	0.4
D	-	0.675 inch 0.75 inch
D_c	-	0.006 inch 0.007 inch
D_l	-	0.006 inch 0.007 inch 0.008 inch
M_c	-	16 20 24
M_l	-	13 15 17 19

Resultant ΔT's were plotted versus M_c for each combination of M_l, D_l, and D_c. One plot was made for each of the two tube diameters (D). A second plot was made of ΔT versus ($D_l^2 \times M_l$) for D_c and M_c. These families of curves were a valuable aid in the selection of the final mesh. Selection of this mesh was again a trade-off between thermal and mechanical requirements. For example, the temperature difference across the boom diameter is strongly dependent upon the cross sectional area of the circumferential wires. As the wire diameter decreases, all other factors being constant, the ΔT increases. Compensation can be made by increasing the M_c in the range of mesh sizes that was considered.

The objective of the analysis was to determine the best compromise of the following characteristics:

a. Increase the number of longitudinal wires of approximately the same size as previously used to lower the unit edge loading and increase the bending moment,

b. Decrease the circumferential wire size to eliminate yielding during flattening, and increase the number of these wires consistant with the trends established on the ΔT curves.

c. Consider higher yield strength of the Elgiloy longitudinal wire as a result of expected better stretching characteristics.

Consideration of all factors, cross plotting to establish expected stretched mesh sizes, liberal reference to the past processing history and experience, and a review of weaving feasibility established the best compromise as 16 × 0.009 Elgiloy warp with 22 × 0.007 Beryllium Copper Alloy 25 shute. This was expected to yield a 16 × 0.0081 × 18 × 0.007 final rigidized screen configuration.

Selection of a weaving source was made on the basis of capability, delivery, and price. Requests for quotations were sent to all potential sources for the Eligloy - copper-beryllium screen, 4 inches wide and 400 feet long (minimum). The most serious objections were to the length combined with the more-or-less gauzy or sleazy mesh. The requested length was four times longer than the industry standard roll, and most weavers were reluctant to attempt one continuous length with a guaranteed warp intact from end-to-end. The National-Standard Company, Corbin, Kentucky was the best bidder on the basis of delivery and capability and was within 1 percent of the lowest price of all bidders. Accordingly, a purchase order was issued to them.

The wire screen was woven at the vendor's convenience on a 36-inch-wide loom. The length was increased to 575 delivered feet per roll. Rolls were shipped on Convair-supplied, demountable reels, which were compatable with both National-Standard and Convair equipment. The purpose of this was to completely protect all edges during shipment and facilitate initial handling. A very close inspection was performed on the incoming screen for uniformity, broken warp wires, and unusable screen areas. The screen was generally of good quality considering the differences in warp and shute wires both in size and physical properties. Some apprehension was felt prior to processing over the occurrence of several groups of three closely-spaced shute wires. It was initially felt that these would all braze together and form a rigid, non-spring-like area in the roll. Optimization of the amount of braze alloy prevented this occurrence. The regularity of some types of nonuniformities was suspected to be caused by starting and stopping of the looms either at shift end or for other more or less regular reasons. No evidence of warp wire discontinuity as a result of weaving was found. Screen slitting to the nominal 4-inch width from the woven 36-inch roll was apparently performed mechanically. All rolls processed were found to have the same pattern of irregularity wherein the slitting rolls crossed over five warp wires in the space of 20 running feet.

This required a full trimming operation for both sides after rigidization and before the Elgiloy stretching operation. The National-Standard screen was not as uniform as that produced by the W. S. Tyler Co. on the previous contract, but it was certainly within acceptable standards.

The certified test report for the screen from National-Standard is reproduced in Figure 1.

2.1.2 PROCESSING EQUIPMENT. Wire screen processing from raw screen to finished booms required the following equipment.

a. Roll and reroll devices for inspection and handling.

b. Rolling mill for calendering.

c. Cleaning facilities.

d. Continuous electroplating equipment.

e. Flux/braze alloy dipping and drying equipment.

f. Brazing equipment.

g. Stretching equipment.

h. Boom forming equipment.

The program requirements or ground rules that were established at the initiation of the program for equipment modifications or construction of new equipment were:

a. Modifications would be made to existing equipment to continuously handle a minimum of 200 feet and preferably the maximum single length of wire screen that was ordered.

b. Modifications would be made to minimize processing manhours and eliminate dependency upon human or "eyeball" feedback for control.

c. Equipment reliability would be increased to attain maximum screen uniformity and product reliability.

An analysis of the equipment developed under NAS5-9597 showed that relatively minor modifications would be required on the vertical processing unit for the flux application and brazing functions and that similarly minor modifications would be required on the boom forming furnace. It was decided to eliminate the electroplating function from the vertical processing unit and to construct a continuous plating line specifically for the application. Tests on a borrowed 2.5-inch rolling mill showed the feasibility of using a similar mill for calendering operations and two mills operating at differential speeds for continuous stretching. Integration of all facilities was to be made through the use of common reels, shaft sizes, and widths.

NATIONAL-STANDARD COMPANY
WOVEN PRODUCTS PLANT

NS NATIONAL-STANDARD COMPANY

Industrial
Wire Cloth
CORBIN, KENTUCKY
Telephone Corbin 528-2141
TWX 606-699-2625

CERTIFIED TEST REPORT

TO: General Dynamics
Convair Div.
3302 Pacific Highway
San Diego, Calif.

Gentlemen:

To the best of our knowledge and belief the following covers the chemical analysis and physical properties of the 237 lbs.; 9 rolls of 4 in. x 5175 ft.; 16 x 22 mesh x .009 x .007 dia. Elgiloy and Beryllium Copper Alloy #25 Industrial Wire Cloth, shipped on P. O. No. City Wire & Iron 8586 dated 5/18/67 to specification ....

CHEMICAL ANALYSIS:

Warp = Elgiloy (Ann.)
Filler = Beryllium Copper Alloy #25 (Ann)

MELT ~~XXXXX~~ NO. (Warp) 630468
(Filler) ----
LOT NO. (Warp) ____
(Filler) ____

WARP:	C	Mn	P	S	Si	Cr	Ni	Mo	Cu	Co	Be	Fe
XXXXX	.15	2.0				20.0	15.0	7.0		40.0	.04	Bal.
XXXXX												

FILLER:	(Nominal Composition)				Be	Ni + Co		Ni+Co+Fe		Cu+named elements		
XXXXX					1.80-2.05	.20min.		.60max.		99.5min.		
XXXXX												

PHYSICAL ANALYSIS:

Average U. T. S. (Warp) 142,900 - 149,600 p. s. i.
(Filler) 74,000 p. s. i.

Average Elong. -10 in. Ga. (Warp) 50 %
(Filler) 64 %

______________________ (Signed)
(Inspector)

STATE OF KENTUCKY
COUNTY OF KNOX

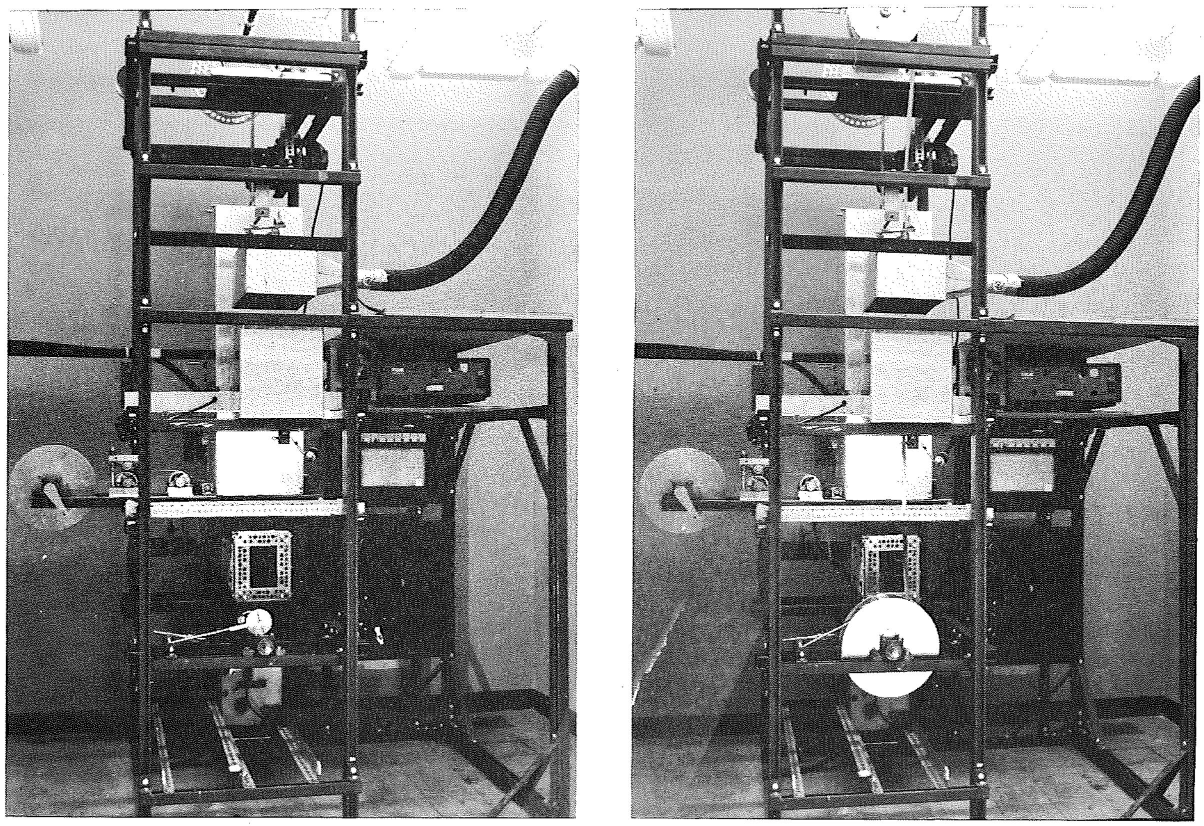
Subscribed and sworn to this 24th day of Aug. 1967 before the undersigned who does hereby certify that under the laws of the State aforesaid he is duly authorized to administer oaths.

Ruby W. Hill (Signed)
Notary Public

Figure 1. Certified Test Report

Roll and reroll devices for handling reels up to 18 inches in diameter were constructed using pairs of shaft hangers with 1-inch bronze bearing blocks. The hangers were mounted on convenient bases for portability and versatility. Hand cranks were utilized effectively. These devices were used in all reel-to-reel inspection, reroll, and slitting operations.

Modifications to the vertical processing unit were minimal to attain the required performance levels. To provide greater flexibility in alignment, self-aligning ball bearings were substituted for the oilite pillow-block bearings previously used. Bearing spacing was changed throughout to accommodate the standardized 18-inch-diameter reel. Finally, instrumentation thermocouples were changed, locations varied, and a general overhaul was given to the continuous brazing furnace. Subsequent to initial processing of screen, a small set of rubber pinch rolls was added to maintain tension on the braze furnace wind-up reel. Figure 2 shows the vertical processing unit in the two modes of operation.



a. Flux Alloy Application Mode

b. Brazing Mode

Figure 2. Vertical Processing Unit

Boom forming equipment required similar minor modifications. An integrated control circuit was added to the furnace for over-temperature and under-temperature alarms, and a detection circuit was added to indicate equipment or process stoppage. Stainless steel wear strips were added to the deforming mandrel to eliminate friction problems. Finally, a dash pot was added to eliminate unnecessary bounce of the movable take-up reel.

A continuous electroplating line was constructed to process entire rolls of screen. This equipment was built from slotted angle iron and oriented in a horizontal position. The operational equipment is shown in Figure 3. Wire screen proceeds from the supply roll in the left foreground, over an idler roll, and into the plating tank. From the

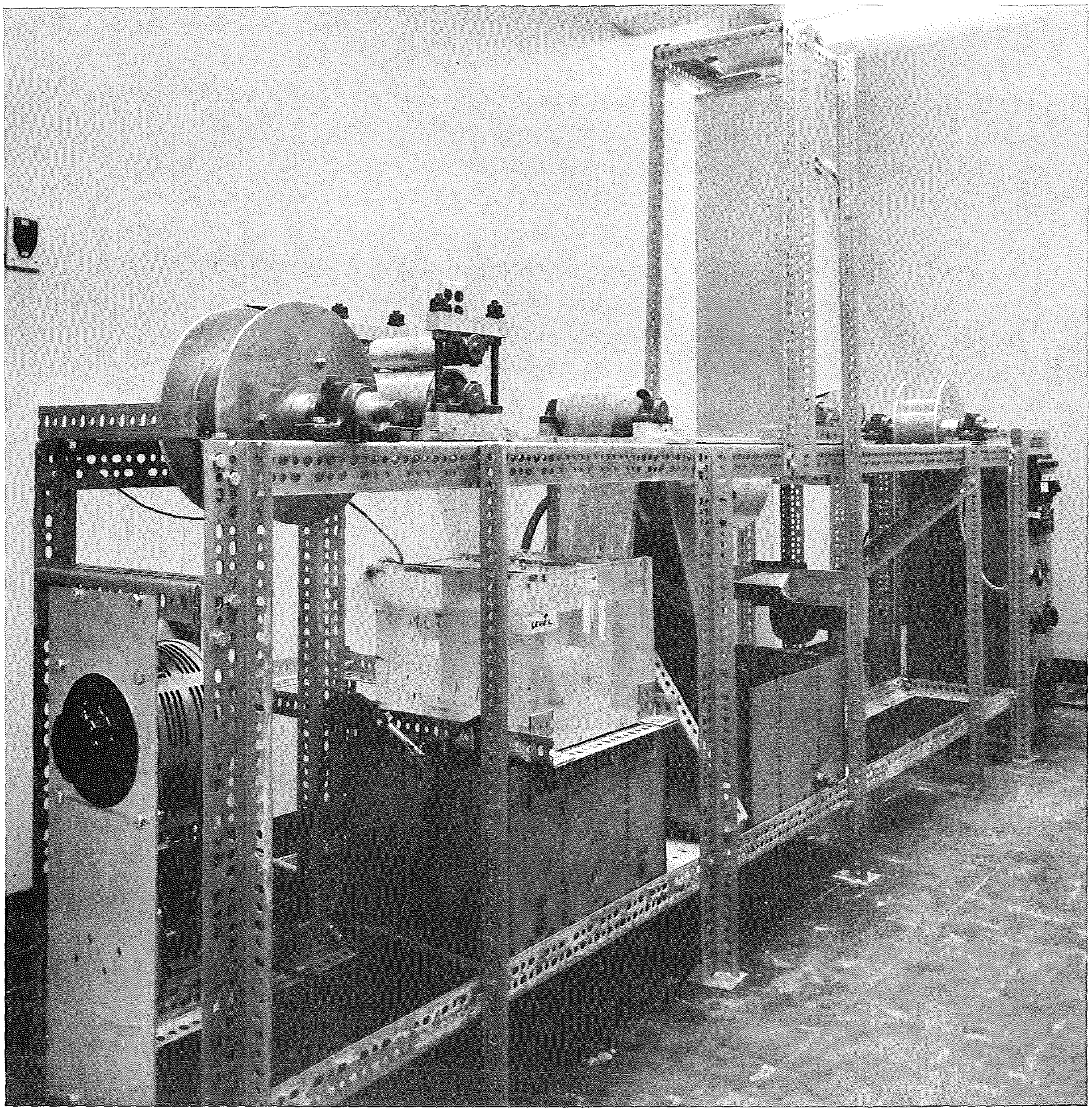


Figure 3. Continuous Silver Electroplating Line

plating tank, the screen is washed twice by flow-down water action, excess water is blown off by a directed fan. The screen is then dried in the tower oven and finally rerolled on the take-up reel in the right background. The plating power supply is shown in the extreme left and the controlled power supply for the tower oven at the extreme right. This continuous plating line had provisions for hot, agitated anodic (or cathodic) cleaning of wire screen on a continuous basis. The cleaning tank is shown beneath the transparent plating tank. Access to this tank was provided by sliding the plating tank to the rear of the unit. This cleaning method was developed as a back-up method to the bulk cleaning method that was actually used. No cathodic cleaning was found necessary in actual practice. Operation of the continuous plating line was fully automatic and required only occasional monitoring while running.

Calendering of wire screen was a definite problem area in the previous contract. The main problem was the very light roll pressure needed to roll or calender the screen nodal points to the required thickness and the availability of a heavy duty Fenn 6-inch, two-high rolling mill. It was found that adequate rolling to eliminate screen sweep-back problems could only be done on this equipment by placing shims between upper and lower bearing blocks and tightening the screw-downs to fix the space between the rolls. A 2.75-inch jewelers rolling mill was borrowed to investigate the potential of this size mill for screen use. Results were impressive and it was realized that re-sizing for the job was an apparent solution. This mill was also used to determine the feasibility of continuous stretching of wire screen. In principle, two rolling mills are used in tandem; the second stand or mill is operated at a higher roll surface speed than the first and the material is thereby uniformly stretched. Investigation showed that sufficient friction could be obtained with a soft aluminum coating on the roll pairs to eliminate any roll slippage. Accordingly, a search was made for suppliers of jewelery-type mills; a suitable type unit was found and two mills were purchased.

Final fabrication of a dual, tandem-pair rolling mill device is shown in Figure 4. Each rolling mill consists of two pairs of rolls, each independently adjustable; and each pair is driven from a common drive.

The upper set of rolls is driven through a 7.5:1 dual-reduction spur gear and the lower set of rollers is driven through a single 5.0:1 reduction. Primary drive for the mills is a 1-hp, 1ϕ, reversible motor coupled to a 10:1 reducer. A common chain drive couples both rolling mill stands. Equal or greater drive speeds can be imparted to the second stand through the use of the appropriate tooth sprocket. On each stand, the lower set of rolls was modified by shrinking a sleeve of 1100 aluminum alloy over each steel roll as furnished. When trued on a lathe, these rolls became the stretch-roll pairs. The take-up reel was powered through a slip clutch for single operator use. Provisions were also made for manual feed and rewind.

An overall view of the rolling mill unit and the continuous boom forming equipment is shown in Figure 5. The only visible evidence of modification is the take-up reel dash-pot at the extreme left portion of the picture.

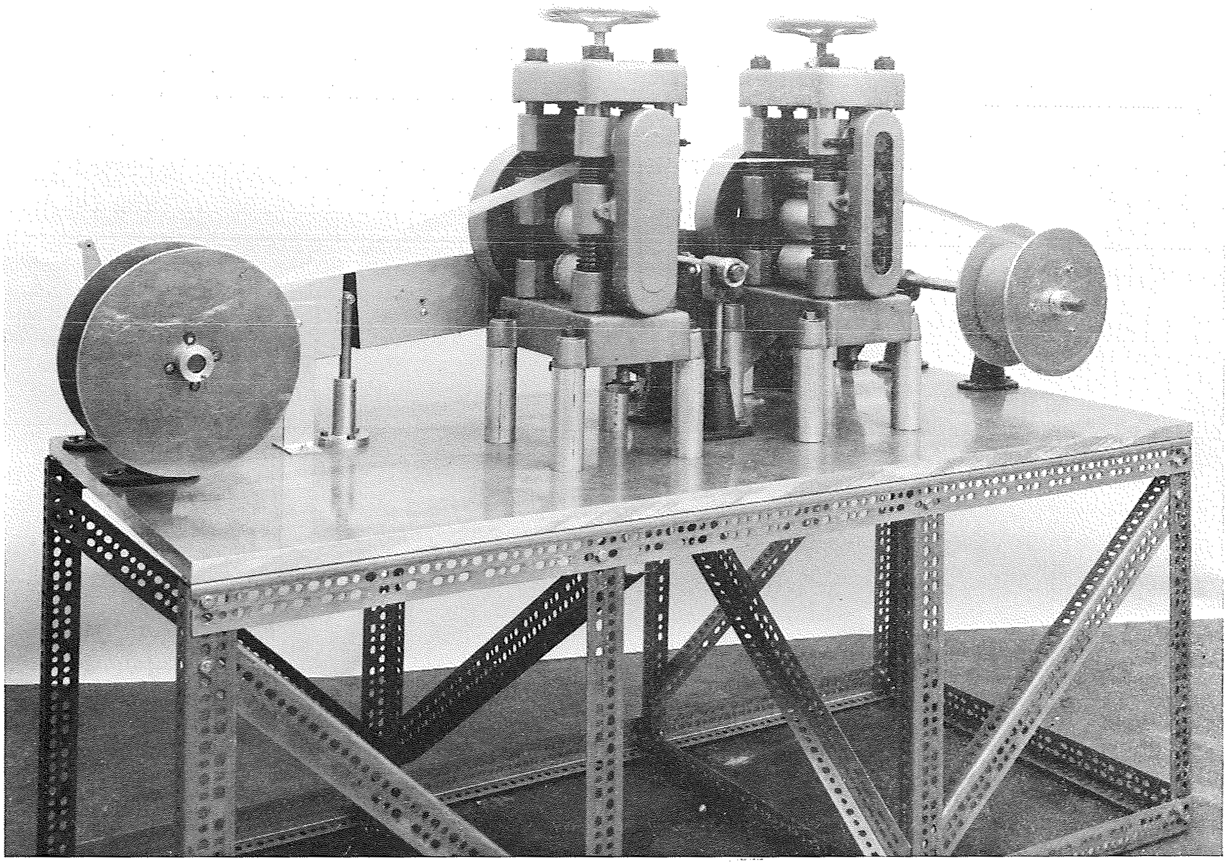


Figure 4. Tandem Stand, Dual Roll Calendering and Stretching Mill

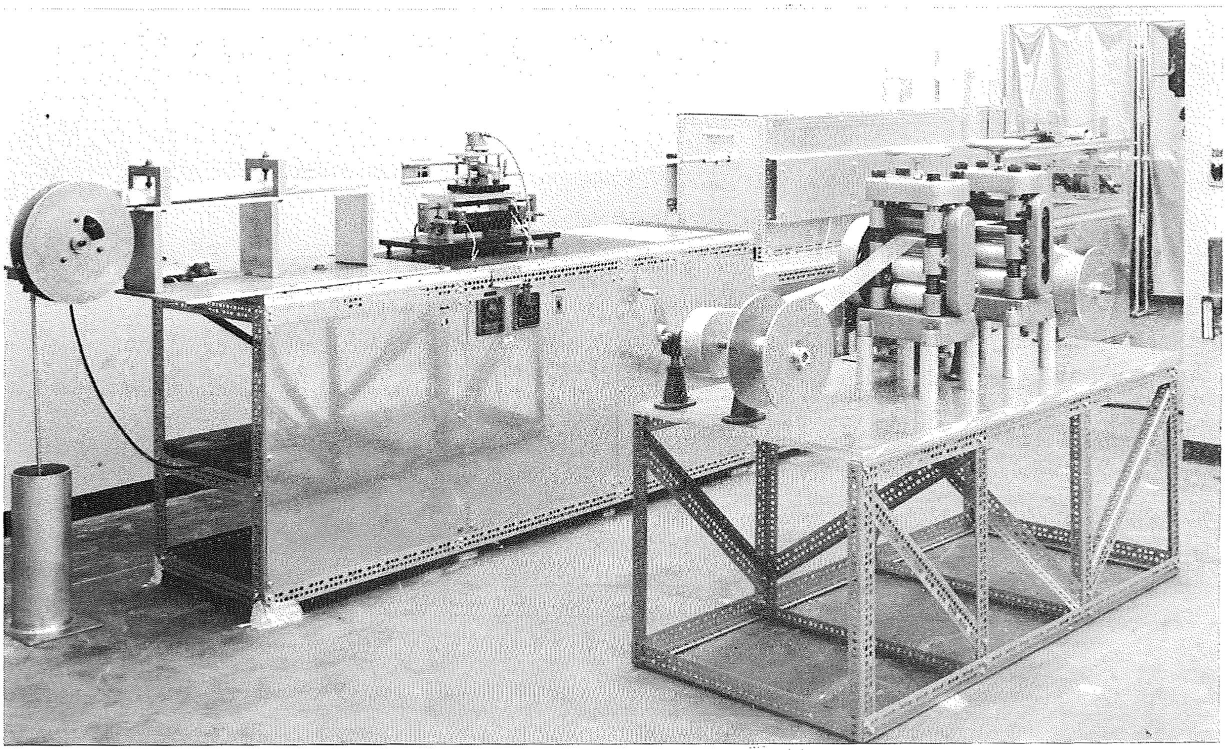


Figure 5. Continuous Boom Processing Unit. Rolling Mill in Foreground

2.1.3 BOOM PROCESSING. A complete processing schedule for wire screen booms is presented in Appendix II. This section discusses the process as finalized for the delivery booms. Process modifications, alternatives, and limits of the process steps are presented.

In general, boom forming was conducted in three major steps:

a. Wire screen rigidization.

b. Elgiloy conditioning and heat treatment.

c. Copper-beryllium heat treatment.

The rigidization phase consists of cleaning, calendering, plating, flux-alloy application, and finally brazing. Elgiloy (longitudinal wire) conditioning and heat treatment steps are stretching, to impart cold work, and thermal treatment, which is a second brazing cycle without additional alloy. The last major step of copper beryllium heat treatment is the so-called boom-forming process.

Incoming raw screen was cleaned prior to any other processing. Since the screen was shipped from the vendor on Convair-supplied, demountable reels, the screen was removed from the reel intact and then bulk-cleaned to remove manufacturing contaminents. Numerous tests were conducted to determine the most efficient schedule. A two-step cleaning process was found to be necessary for complete cleaning and degreasing of the as-received screen. Heavy sporadic deposits of grease on the screen were removed by a simple soak in an organic solvent. Amyl acetate (lacquer thinner) proved excellent as the first stage, while hot, ultrasonic-soak cleaning in a detergent-type solution removed other oils and dirt. A two-hour-minimum soak with (time permitting) 24 hours preferred was established. A minimum of five complete dip-and-drain rinse cycles was required to completely free the screen roll of cleaner. Forced convection drying at 220° F was required to dry the screen in the bulk condition.

A complete inspection was conducted on every roll of screen processed. Although the screen deficiencies that were discussed in Section 2.1.1 were initially considered deleterious to the uniformity of finished boom, subsequent experience showed that they were of minor significance. Of major importance at this time was the removal of loose and irregular warp (longitudinal) wires, which were produced as a result of mechanical slitting of the screen at the mill. These loose wires, if they were allowed to remain through further processing, could have caused severe interference with the processing.

Calendering was conducted primarily as previously developed, using the upper rolls of a single mill of the previously discussed equipment. A single-pass schedule was used to reduce the thickness to 12.5 mils.

Bulk cleaning of the calendered screen was performed just prior to the silver plating operation. The primary reason for the change to hot Turco Caviclean No. 2 (from the previously used Oakite 165) was the complete elimination of residual films. Silver-plating was conducted on the wet screen without an intervening drying cycle. Silver-plating as a process was basically unchanged from that previously used.

The flux-alloy slurry was optimized for the specific mesh screen used in this modification and refinement program. The actual alloy content was reduced from 2.78 lb to 2.40 lb avd per 100 pounds of flux. This change gave a minimum excess of brazing alloy to allow full nodal fillet formation with a minimum of braze alloy overaly on the wires. Both flux-alloy application and brazing cycles were fundamentally unchanged from those previously developed. Thorough post-braze cleaning of the screen to remove the flux was conducted using 140° F water followed by thorough rinsing and forced convection drying.

Post-braze inspection was conducted in conjunction with the first edge-trimming operation. Through analysis of the type and position of unbrazed areas, it was learned that most of these areas rebrazed to fully acceptable standards during the Elgiloy heat treatment. Inspection was done initially on a purely visual basis. Edge trimming of the brazed screen was conducted to trim the screen roll to a uniform number of warp wires from one end to the other. In this condition, each warp wire was continuous from end to end. During this trimming, which was done manually with electric scissors, it was readily observed, both by feel and by cutting operation, whether the screen was fully brazed, partially brazed, or totally unbrazed.

Stretching of the rigidized screen was done primarily to impart cold work to the Elgiloy in order to condition it so that it would respond to heat treatment. The desired percent of cold work for optimum response to heat treatment approaches 47 percent, but 25 percent cold work was found to be more realistically attainable. Stretching was initially conducted on the dual-stand rolling mills on a continuous basis. Using this device any percent-stretch, up to breaking, could be continuously accomplished. Lack of straightness of the stretched screen became a major problem and prevented utilization of this method. The backup method of gross stretching of the entire roll of screen (using a dead-man and a cable and winch) was used for all delivery booms. Actual stretch percentage was calculated on the basis of mesh count rather than physical measurement of additional length induced. This averaged 22 to 24 percent at a rate of stretch of 1 percent per minute.

Cleaning was conducted prior to the second calendering operation only to remove tars and dirt picked up during the stretch operation. Calendering was again conducted to redistribute crimp from 100 percent in the shute direction to approximately 20 percent warp, 80 percent shute. A thorough cleaning then followed in preparation for the flux application step.

The Elgiloy heat treatment of stretched or cold-worked screen consisted of a second continuous brazing thermal cycle. This cycle, being a well controlled, accurate, short-time-high-temperature treatment, imparted the desired properties to the Elgiloy without affecting the nominal annealed condition of the copper-beryllium. No changes in the procedure or the cycles were made over those previously developed. Post-braze cleaning followed as previously described.

A thorough visual inspection was conducted prior to trimming to the required final width. The purpose of the inspection at this point was to reveal any unfavorable edge conditions and to confirm rebrazing of any previous marginal areas. Trimming to the desired width was again conducted using electric scissors. Screen was trimmed to 2.52 to 2.54 inches (42 warp wires). During the trimming operation the shute wires were cut flush with the desired warp wire. This placed a definite force on the braze joint where each shute wire is joined to the screen edge wire. By observation of the very few ends that are displaced by the cutting action of the scissors, a firm measure of the percent of brazed joints can be made over an exceedingly large number of joints. All screen produced during this contract exceeded 99.95 percent brazed.

A second stretching operation following the trim to final size was added to the procedure. The screen was stretched 0.3 to 0.4 percent to ensure full straightness of the rigidized screen and to eliminate as much crimp from the longitudinal wire as possible. Although this crimp elimination increased the measured thickness, it decreased the stacking from 14 mils to 11.4 mils through more favorable nesting of the screen.

Silver-plating of the rigidized screen was conducted on the continuous equipment previously described. Identical cleaning procedures were used. An additional surface preparation was found to be necessary to remove occasional oxide fromed during previous thermal treatments where flux coverage was not complete. This consisted of a 20 percent sulfuric acid immersion at room temperature for 15 minutes for black oxide conversion to red, followed by a 1-minute dip in 15-percent nitric acid at room temperature for oxide removal and brightening. Silver-plating was done on wet, as-rinsed screen. Similar plating techniques were used as for the first silver flash to promote brazing. In this step however, brighteners were added to the plating bath.

Boom forming was conducted automatically on the continuous furnace. Numerous minor changes in the actual procedure were made over the course of the contract. The basic heat treatment cycle for the beryllium-copper alloy 25 was changed from 1 hour at 650° F to 1 hour, 5 minutes at 675° F. This was an optimization procedure conducted on the new configuration wire mesh. The length of the original 0.680-inch-ID female mandrel was shortened from 36 to 18 inches and the effective length of the 0.625-inch-OD male furnace mandrel was lengthened 18 inches to compensate. These changes were made to more closely control the as-formed diameter of the boom. Continuous boom lengths were wound on the standard 7-inch reel hub and stored in this condition until ready for use. Maintenance of a clean argon atmosphere in the furnace eliminated the need for any further cleaning.

2.1.3.1 Wire Screen Boom Handling. The 16 by 18 mesh, 0.0082 by 0.0070-inch wire screen used during the program was found to be a much easier configuration to handle than the screen based upon the 12 mesh warp in the previous contract. Throughout the rigidizing and heat treatment processing procedures it was found that the reduced sleazyness of the 16 mesh warp made all handling far less critical. This was especially true with the formed boom.

It has been determined in Contract NAS5-9597 that all handling of the formed boom had to be done on a mechanized basis to prevent yielding of the outer two edge wires. With the new mesh and wire sizes some manual handling of the formed boom became possible. No tendency for outer edge wire yielding was found when the booms were uniformly handled. Manual procedures were used in loading the 150-foot boom lengths onto the deployer reels as follows.

a. A 36-inch-wide PVC plastic sheet was laid out on a hallway floor for cleanliness.

b. One end of the boom was firmly held while the boom was unrolled from the 7-inch diameter hub upon which it had been wound on the boom-forming furnace.

c. The deployer and fitting was attached and the 150-foot boom length then self-rolled upon the deployer reel.

This method of handling was used since it was not known at the time what the effect of reel-to-reel loading would be. In later tests, however, it was determined that the reel-to-reel method was also a usable method, producing no deleterious effects upon future boom performance. Caution is noted, however, that in this method two accurately aligned reel must be used and that tension on the screen boom is mandatory at all times.

It is recommended that all boom handling be performed using equipment applicable to this specific use. Manual handling tends to be risky to the uninitiated, since kinking of long lengths could happen unexpectedly.

2.1.4 BOOM TESTS. Boom testing was limited to determination of the pertinent physical properties, bending strength, and thermal deflection. Flotation tests for straightness were not carried out but straightness will be discussed. Four complete rolls of screen were processed to booms during the program. Roll Numbers 1 and 2 were primarily for development and testing, while Numbers 3 and 4 were destined for delivery hardware. Testing throughout closely followed the procedures used in Contract NAS5-9597. Deviations are noted.

2.1.4.1 Bend Strength Tests. Table 1 summarizes the bending strength of all of the processed booms. It should be noted that all tests were conducted on the Convair combined torsion and constant bending moment apparatus. In this test method a standard constant 0.005 ft-lb of torque was applied during application of the bending loads.

Table 1. Wire Screen Boom Bending Strength

Roll Identification	Combined Bending Moment (ft-lb +0.005 ft-lb torsion)		Overlap at Seam (in.)
	Seam in Tension	Seam in Compression	
1A	1.00	0.95	1/16
1B	---	1.03	1/16
2A	1.22	0.935	1/16
2B	1.28	0.92	1/16
2B	1.21	1.05	3/16
3A	1.12	0.99	1/16
3A	1.22	1.06	3/16
4B	1.25	0.96	1/16
4B	1.31	1.04	3/16

Note: All tests are average of two or more tests.

2.1.4.2 Thermal Deflection Test. One 16 by 18 mesh Elgiloy - Beryllium Copper Alloy 25 boom, 3/4-inch diameter, fully representative of delivery boom material, was tested to determine the direction and magnitude of deflection from solar radiation in vacuum. The test was conducted similarly to those performed under Contract NAS5-9597. Testing was performed as follows.

A 1-inch piece of 0.7-inch OD glass tubing was inserted into one end of a 29-3/4-inch-long boom specimen and the specimen wrapped with teflon tape over the one-inch length. The specimen was then mounted on a sealed vessel containing a Shackman and Sons Mark 3 autocamera having a 3 x teleconverter on a 135 mm lens. The camera was then focused through the length of the boom onto a single wire end that had been purposely bent into the camera's view. This strand or wire end was on the seam of the boom and was used in conjunction with the crosshairs on the camera lens for determining boom deflection.

The assembly was mounted in the vacuum chamber as shown in Figure 6 with the boom seam 180 degrees from the radiation source. (Run 1)

The chamber pressure was reduced to 10^{-6} mm Hg, with the chamber coldwall at -320° F and the specimen was exposed to 450 btu/ft^2-hr solar simulation for 2040 seconds. Photographs were taken at 10 second intervals for the first 9 minutes and

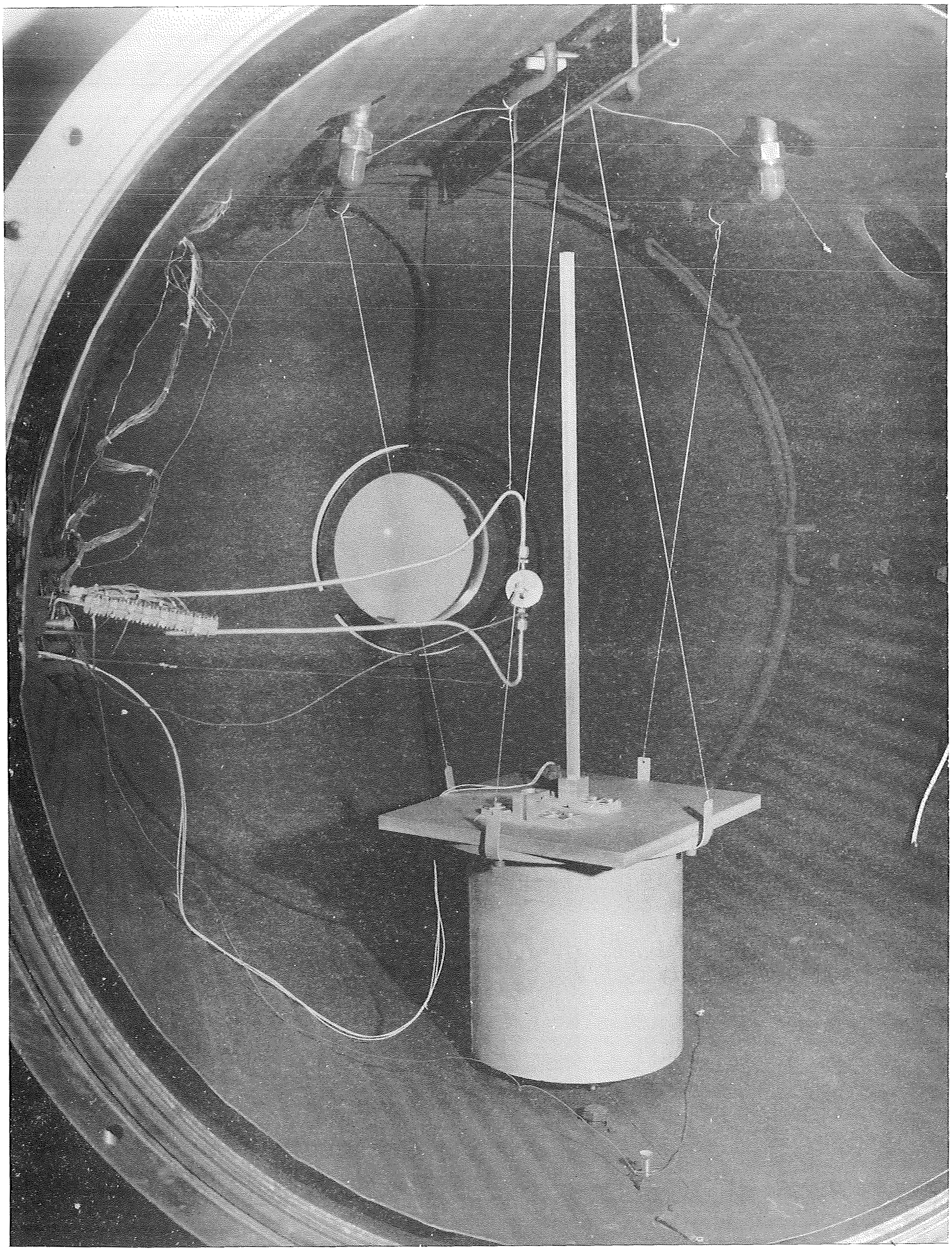


Figure 6. General Test Setup for Thermal Deflection Showing Boom, Camera Housing, and Calorimeter Inside Test Chamber

at 1 minute intervals for the remaining 25 minutes. Run 2 was identical to Run 1 with the exception that the boom seam was located 90 degrees from the light source.

Tables 2 and 3 summarize the boom deflections for Runs 1 and 2, respectively. These data are plotted in Figure 7 as deflection versus time. Since only two runs were made, it is difficult to thoroughly analyze the results. It is evident that the effect of the low thermal conductivity across a small boom seam is quite pronounced. Both tests showed a long time period required to attain stabilization. Note that both booms reached the same general level of deflection at this time. Comparative tests, using a 1/2-inch-diameter copper beryllium tape boom, were made at a previous time. The tape, under identical conditions, stabilized at from 20 to 30 seconds and reached a deflection of almost 0.1 inches for the same length of boom, or from 10 to 14 times the deflection of the wire screen boom.

It should be noted that temperature measurements were not made on any of the boom tests. Previous experience and test analysis showed that temperatures measured were probably those of the thermocouples rather than the wire screen configuration.

2.1.4.3 Boom Straightness. Straightness of the fabricated 150-foot-length booms was not determined by flotation or similar methods. A measure of the overall straightness for each boom was indirectly determined, however, during the loading of each of the deployer reels with the delivery booms. In the procedure previously described in Section 2.1.3.1, the individual 150-foot boom lengths were physically laid out in a hallway on transparent PVC sheet on a tile floor for reel loading purposes. Because of the low friction of such an arrangement, the boom was able to assume a preferred

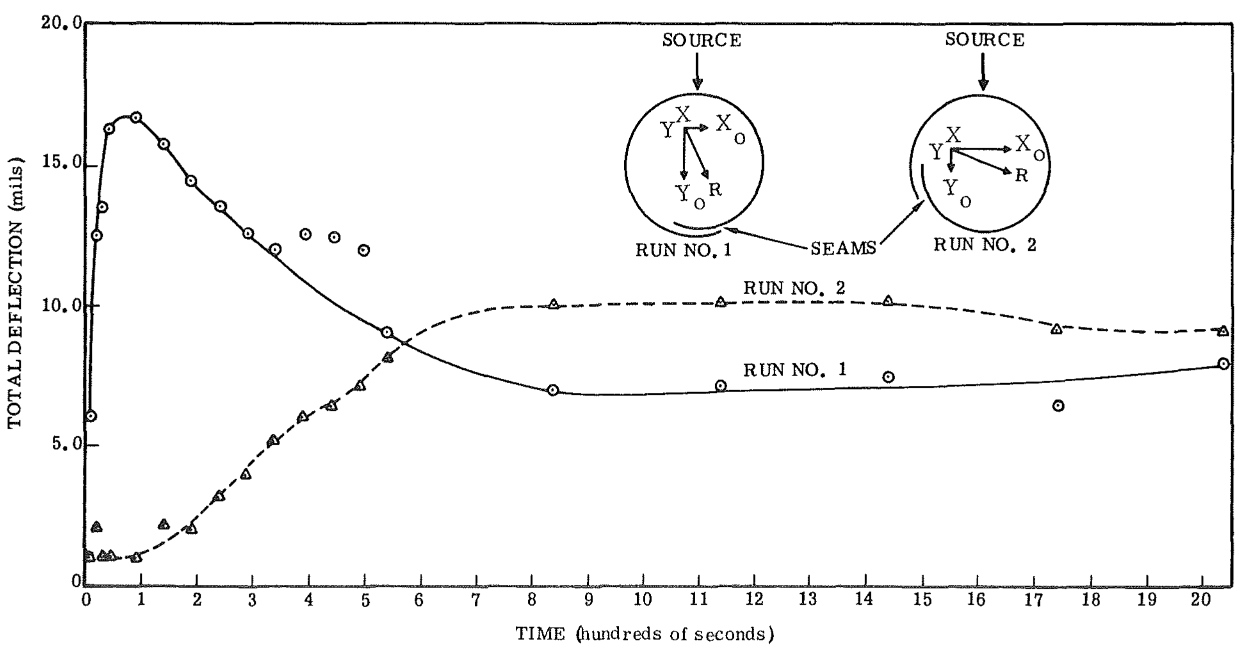


Figure 7. Boom Deflection Versus Time

Table 2. Boom Deflection, Run 1

Time (sec)	Frame No.	$X - X_0$ (inches)	$Y - Y_0$ (inches)	Resultant Deflection (inches)
0	1	---	---	0
10	2	-0.002	0.009	0.0063
20	3	-0.004	0.012	0.0126
30	4	-0.006	0.012	0.0134
40	5	-0.006	0.015	0.0161
90	10	-0.005	0.016	0.0167
140	15	-0.005	0.015	0.0158
190	20	-0.004	0.014	0.0146
240	25	-0.004	0.013	0.0136
290	30	-0.004	0.012	0.0126
340	35	-0.004	0.011	0.0120
390	40	-0.004	0.012	0.0126
440	45	-0.006	0.011	0.0125
490	50	-0.004	0.011	0.0120
540	55	-0.004	0.008	0.0090
840	60	-0.005	0.005	0.0070
1140	65	-0.006	0.004	0.0073
1440	70	-0.007	0.003	0.0076
1740	75	-0.005	0.004	0.0064
2040	80	-0.008	0.000	0.0080

Table 3. Boom Deflection, Run 2

Time (sec)	Frame No.	$X - X_0$ (inches)	$Y - Y_0$ (inches)	Resultant Deflection (inches)
0	1	---	---	0
10	2	0.001	0.001	0.0010
20	3	-0.002	0.000	0.0020
30	4	0.001	0.000	0.0010
40	5	0.000	-0.001	0.0010
90	10	-0.001	0.000	0.0010
140	15	-0.001	-0.002	0.0022
190	20	0.000	-0.002	0.0020
240	25	-0.001	-0.003	0.0032
290	30	0.000	-0.004	0.0040
340	35	-0.001	-0.005	0.0051
390	40	0.000	-0.006	0.0060
440	45	-0.002	-0.006	0.0063
490	50	-0.001	-0.007	0.0071
540	55	-0.001	-0.008	0.0081
840	60	0.000	-0.010	0.0100
1140	65	-0.001	-0.010	0.0101
1440	70	-0.002	-0.010	0.0102
1740	75	-0.001	-0.009	0.0091
2040	80	-0.001	-0.009	0.0091

orientation. It was noted in working with the boom lengths that the booms assumed a position that was essentially straight and, more specifically:

a. No portion of the boom deviated from a continuous tile line by more than 2 inches, and

b. The ends of the boom were within 3 inches of a centerline through the deployer.

It is noted that this incidental method for testing did not allow for completely normal boom rotation and that flotation tests may show completely different results. It is indicative, however, of the elimination of outer wire yielding during processing. If yielding had occurred, a definite curve of the boom would have been noted even with this method.

2.1.5 DELIVERED BOOMS. Physical specifications for the booms delivered to Goddard Space Flight Center are given in Table 4. All booms were supplied prepackaged on reels for the deployment mechanisms.

Table 4. Physical Specifications of Delivered Booms, Elgiloy - Beryllium Copper Alloy 25 Wire Screen

Boom No.	Length (ft)	Boom Diameter (in.)	Mesh Size		Open Area (%)	Wire Diameter		Weight/ 100 Ft (lb)
			Warp	Shute		Warp (in.)	Shute (in.)	
3A1	150	0.74	16.0	18.0	76.1	0.0082	0.0070	1.43
3A2	150	0.74	16.0	18.1	76.0	0.0082	0.0070	1.42
4B	150	0.73	16.0	18.0	76.1	0.0082	0.0070	1.43

2.2 SPLICING

A thorough analysis of splicing or joining of wire screen was initially conducted to determine the most productive course of action. Splicing, in order to be considered successful for gravity gradient boom applications, must be done such that the physical and mechanical properties are essentially unchanged. The splice, furthermore, must have high reliability and be made (preferably) simply and easily with a minimum of equipment. The analysis showed that:

a. The longitudinal (warp) wire was readily weldable.

b. As-woven screen was uniform to permit matching of warp wires on an end-to-end basis.

c. Rigidized wire screen could not be matched on an end-to-end basis from one roll to another.

d. Wire spacing of the 16 x 22 mesh screen was adequate to permit standard joining techniques to be used on individual wires.

On the basis of this analysis, splicing was considered to be more valuable and productively accomplished on raw screen.

2.2.1 SPLICING DEVELOPMENT. Splicing development was initially conducted on single 9-mil Elgiloy wires to investigate techniques for joining strands either end-to-end or with a small overlap. End-to-end (butt) joints were ruled out because it required completely unavailable equipment. Emphasis was then placed on acquiring and developing a suitable overlap joint. The most consistantly successful lap joints were made with the wires placed side by side and resistance welded together. A chisel-shaped electrode, placed across both wires simultaneously, formed a molten zone in each wire when current was passed, and the electrode pressure then forged the wires, forming a joint. This was not conventional wire-to-wire welding in which one wire is placed over the other and resistance welded in standard fashion. Single strand tests showed that an average joint efficiency of 80 percent was obtained with this technique. A silver brazed resistance welded joint in the single strand increased the joint efficiency to 100-percent.

The single wire technique was adapted to the 16 x 22 mesh raw screen using a universal-type tooling concept. The welding apparatus is shown in Figure 8. A Hughes Model VTW 29 B Stored Energy welding power supply was used with a Hughes Model VTA-42 welding head. The head mounting was modified to accept a large flat electrode instead of the usual adjustable arm-type holder. Upon the flat electrode or conducting surface an aluminum fixture for holding the raw screen is placed. A copper alloy insert was used in the fixture for the rigid electrode. Scribed lines on the fixture aided in exact alignment of the two cut ends of the screen. Welding energy was 1 3/4 watt-seconds using an electrode force of 25 grams. Ten-power binocular magnifiers were found advantageous during splicing, as was a variety of tweezers, probes, and scissors.

The splice overbraze with silver brazing alloy was straight foreward. Several techniques for wire brazing are possible, depending upon the operator's skill. The very simple setup required is shown in Figure 9. A Henes Manufacturing Company, Water Welder Model V, was used as the basic torch. One technique for brazing the joint used flux protection for all of the wires surrounding the joint area and required a 29-gauge tip with a 0.0040-inch orifice. An alcohol vapor "booster" provided additional Btu with this necessarily small tip. In addition to the surrounding wire flux protection, a minute dab of braze alloy powder mixed with flux was individually added to each joint. Brazing then followed. A second technique, requiring somewhat more skill or practice, uses a 30-gauge tip with a 0.0030-inch orifice and a straight oxygen-hydrogen flame. Each joint is painted with a minute dab of alloy-flux slurry and then the actual joint, only, is heated with the all-but-invisible flame. Ten-power binocular magnifiers must be used for both techniques.

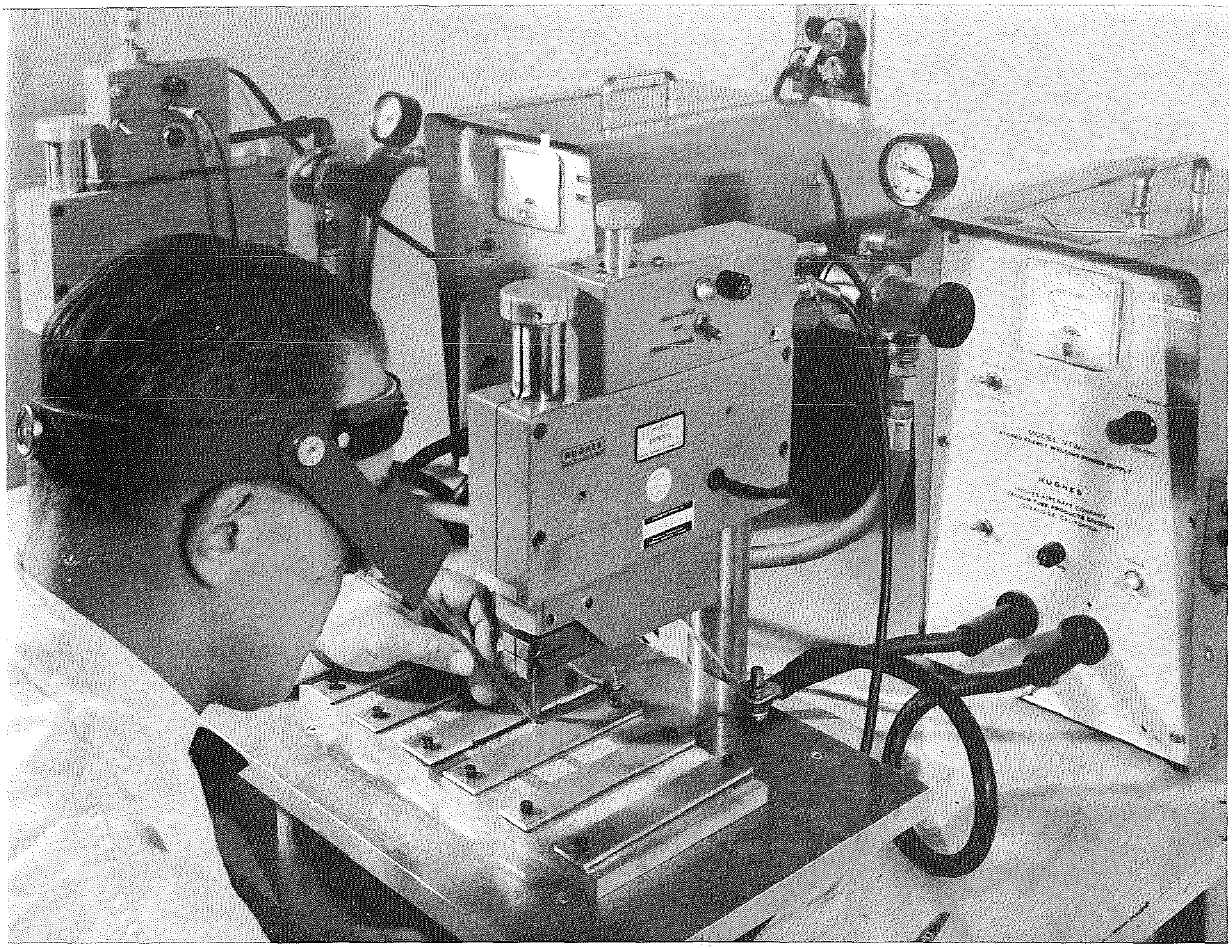


Figure 8. Resistance Welder for Screen Boom Splicing

The splice on raw screen has one major drawback, it must be completely uniform and strong enough to withstand all subsequent processing including stretching or cold work. Because of this, other splicing techniques and methods were investigated and pursued. Similar welding and brazing techniques were found to be wholly adequate for splicing fully rigidized screen either before or after Eligiloy heat treatment. Since there were to be many splices in the same roll of screen for delivery test splice samples, mechanical and physical test splices, and for storage and flexure testing, this latter method was selected for production of all of the joints or splices. The full splicing procedure is given in Appendix III. The advantage of splicing after all processing procedures, except for boom forming, are performed is that fewer joints need be welded (narrower strip - trimmed to final size), and the rigid screen is far easier to handle. The difficulty or drawback is the very likely mismatch from one roll of screen to the other. Actual splicing of screen to obtain unlimited lengths in practice could easily use a raw screen splice to aid in processing rolls end-to-end, reinforce the splice area while stretching (a tuck-fold with a clamp bar), followed by remaking the splice with now-matching ends. This would, of course, eliminate the ever-present potentiality of screen breaking while stretching.

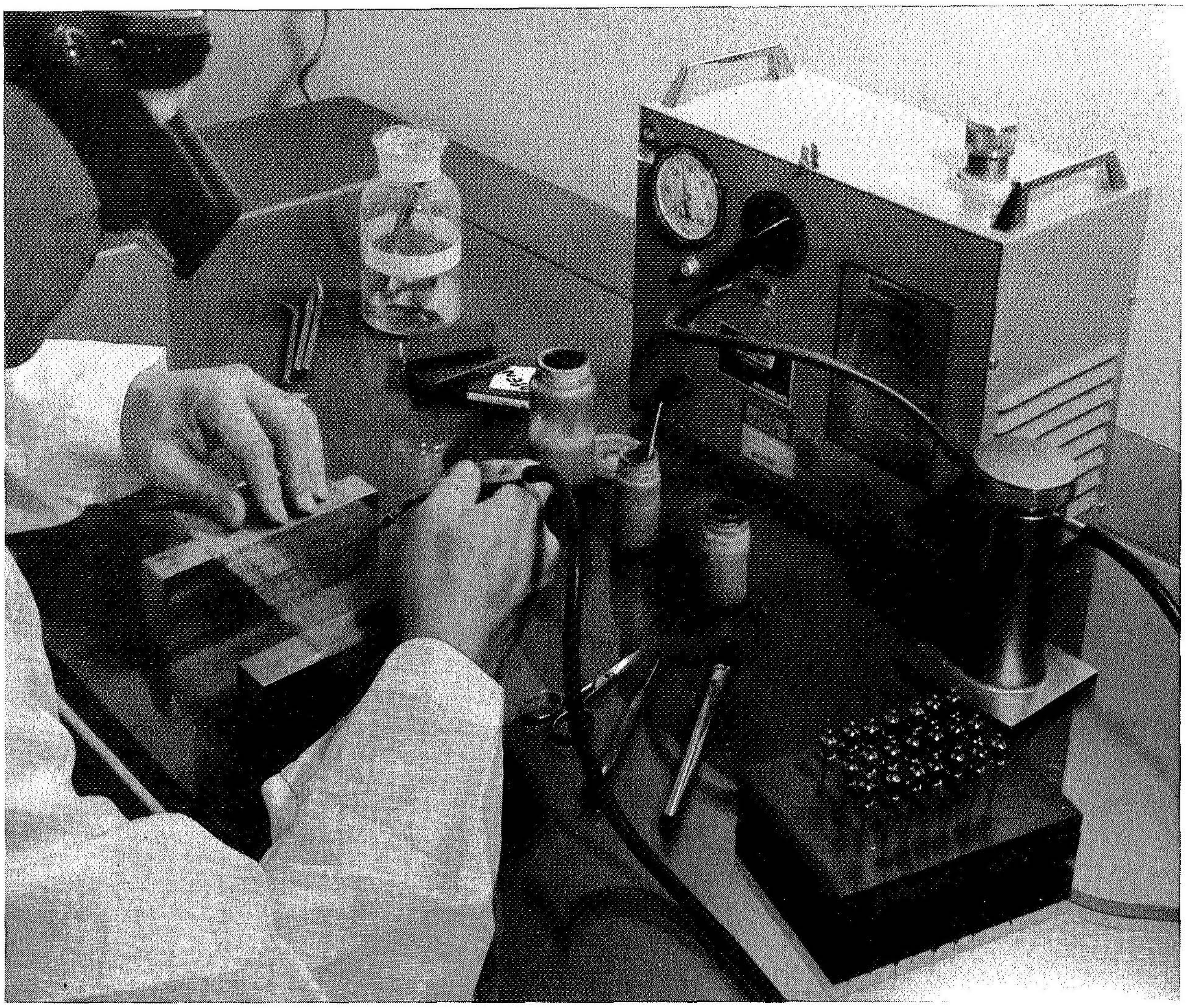


Figure 9. Manual Splice Brazing Setup

A third method of splicing was used for convenience during the processing of booms. The back end of one roll of screen being processed into booms was spliced in the following fashion to the front end of another roll to continue processing without interruption.

a. Both screen ends were masked with plater's masking tape, leaving 1 inch of screen exposed. The exposed ends were immersed in 50-percent nitric acid to remove the copper beryllium cross wires, and rinsed to remove the acid.

b. The bare Elgiloy wires were trimmed normal to the screen edge to a length of 1/8-inch.

c. Elgiloy wires were butted together on an 1/8-inch-wide strip of foil and tack welded in position.

d. A braze to foil joint was then made at each butt joint. The foil edge was trimmed to screen width and the splice was finished.

This type of joint probably shows more promise than any of the other types since it is a more easily accomplished joint, is apparently as strong as the Elgiloy warp, and is adaptable to all screen even to joining one mesh size to the other. It is suggested that the overall effect of a 0.060-inch to 0.10-inch strip in such an application would have extremely little, if any, effect upon any of the screen boom properties.

2.2.2 SPLICE TESTING. Roll No. 2A was processed as a splice and splice test roll. One 85-foot section was made up for splices only, as follows:

a. Five pairs of splices spaced at 12-inch intervals, 36 inches apart for delivery items and bend test specimens.

b. Eight splices, spaced five feet apart for storage and flexure testing.

c. Six splices spaced at 24-inch increments for backup and additional testing.

Splices were made according to the procedure given in Appendix III.

2.2.2.1 Bend Tests. The Convair combined torsion and constant bending moment method was used to determine the bending strength of the splices. A 12-inch specimen was used with the splice centered in the apparatus. Table 5 summarizes the results of this testing. Three specimens with the seam in tension and three specimens with the seam in compression were tested. Although the combined bending moment with the seam in compression was lower than the unspliced material, failures occurred a minimum of two inches away from the splice. In no sample could the splice be considered as the focal point of failure.

Table 5. Spliced Wire Screen Boom Bending Strength

Roll Identification	Combined Bending Moment ft-lb + 0.005 ft-lb torsion		Remarks
	Seam in Tension	Seam in Compression	
2A	1.22	0.935	1/16 inch overlap.
2A	1.15	---	Splice samples with failure 3/4 inch and 1 inch from the splice.
2A	---	0.87	Splice samples with failures 2 and 3 inches from splice.

Note: All tests are average of two or more tests.

2.2.2.2 Storage and Flexure Testing. Storage anf flexure testing was performed according to the method given in the Section A.2.b. of the Statement of Work. All wire-to-wire joints in the splices withstood the entire one-month-long test. Straightness of the joint section was determined with the test section remaining attached to a deployer reel, upon which the storage test was conducted. No change in the straightness of the test specimen was noted over the course of the test. Joint areas were detectable only by the slight change in the open area at the splice.

2.2.3 DELIVERED SPLICES. Three 36-inch-long boom sections, each having two splices at approximately 12 and 24 inches from one end, were delivered to NASA Goddard Space Flight Center under the terms of the contract.

2.3 DEPLOYMENT MECHANISM

Modifications were made in the boom deployer delivered under Contract NAS5-9597 such that the mechanism would survive a simulated launch environment as for the ATS satellite. The design was modified to meet the temperature, humidity, and vacuum test specifications for the ATS satellite per Specification S2-0102.

The boom deployer previously delivered is shown in Figure 10 for reference. The mechanism had a bare weight of 7 pounds and, because of the side plate and post construction, was not considered able to withstand vibration tests. The fundamental concepts of 1) deployment, using "rubber" rollers to drive or pull the screen from a reel having controlled back-tension, and 2) reroll or retraction, using a powered reel for proper tensioning of the screen and driven "rubber" rollers for screen retraction, were considered sound. Design modifications were therefore undertaken to reduce the weight but increase the rigidity for resistance to vibration, and make the deployer compatible with the specification.

2.3.1 DEPLOYER DESIGN AND MATERIALS. The modified deployer design was fundamentally unchanged from the previously delivered model. Modifications were made throughout, however, with the obvious difference being the external configuration. The engineering prototype and test model of the improved deployer is shown in Figures 11 through 13. An assembly layout of the deployer is shown in Figure 14 for clarity in the following discussion.

The intent of the modification of the deployer was not to redesign but to improve and modify where required. The basic dual-motor concept was retained along with the spring-loaded, powered roller mechanism and the clutch-driven reel. The parallelogram nozzle for guided deployment of the boom in the required constant angular direction was kept unchanged. Preliminary analysis of the improved mechanism showed that it would be feasible to design the reel attachment such that the reel could be readily interchanged without disassembly of the entire mechanism. The reel design, itself, was examined and it was found that it could be made of simpler fabrication

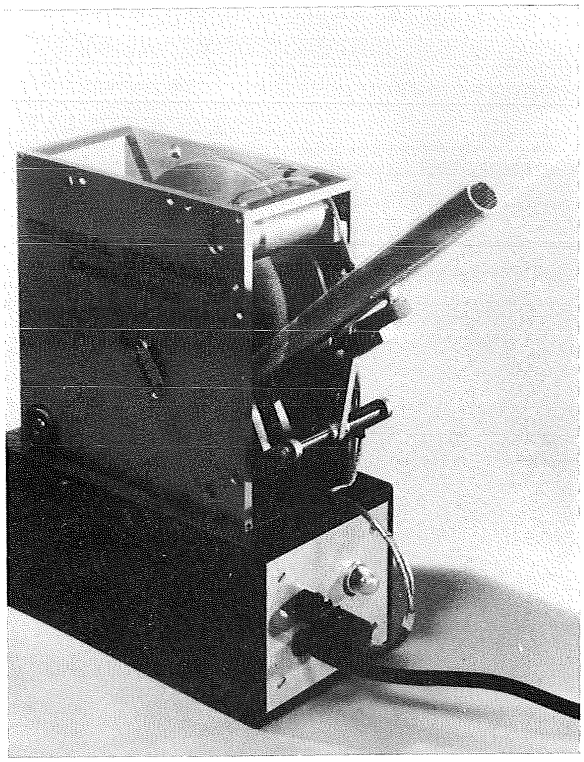


Figure 10. Deployer Developed Under Contract NAS5-9597

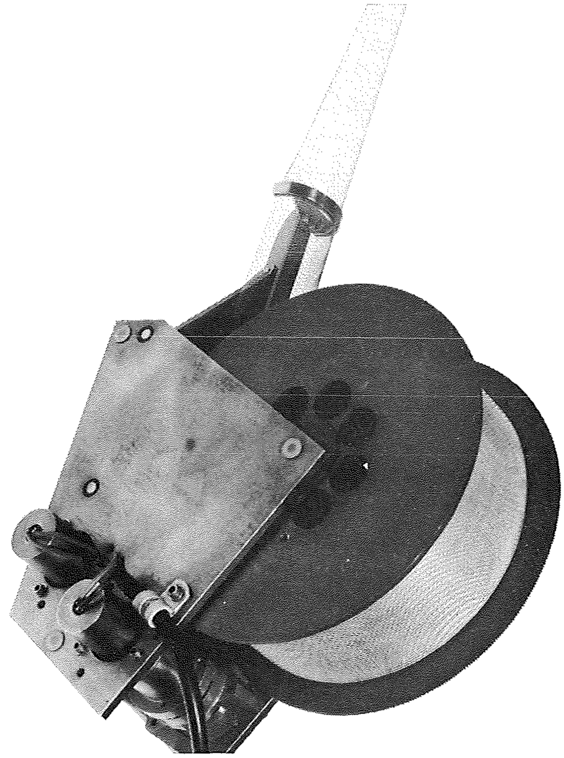


Figure 11. Oblique View of Deployment Mechanism - Motor Terminal Side

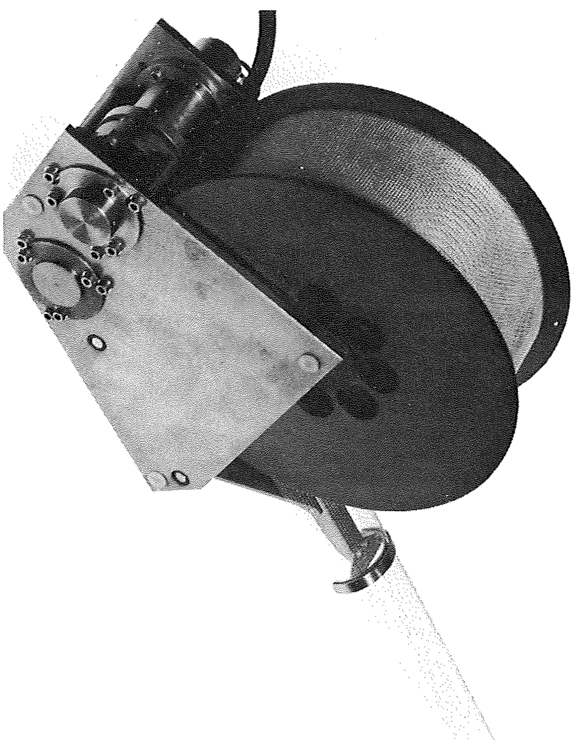


Figure 12. Oblique View of Deployment Mechanism - Gear Drive Side

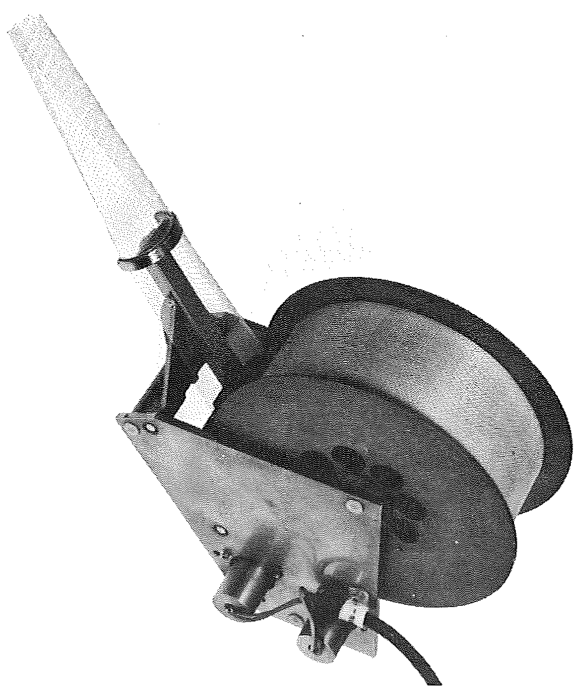
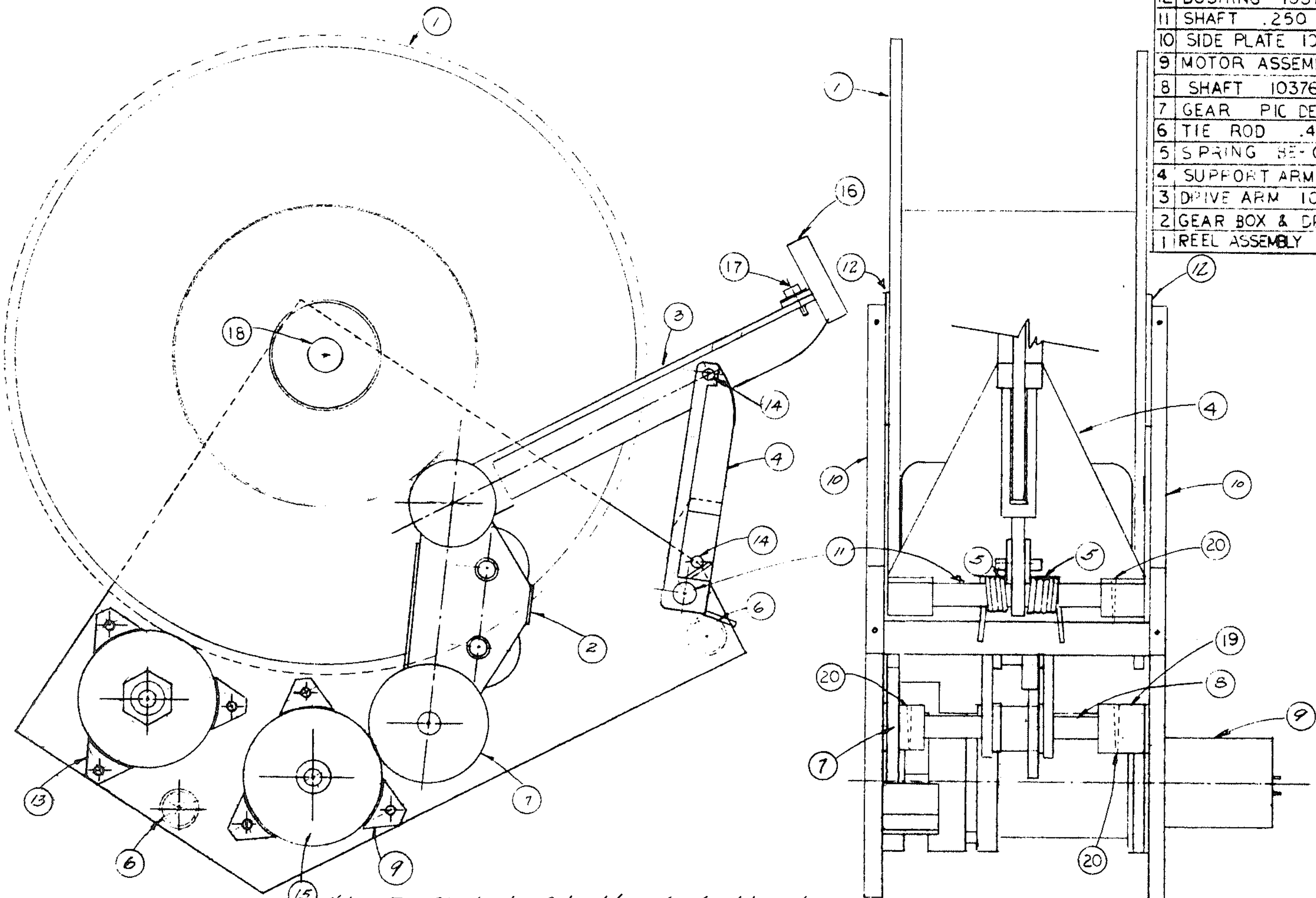


Figure 13. Front Oblique View of Deployment Mechanism Showing Screen Boom Guide

20	TAPER PIN 7/0 CUT TO LENGTH
19	BUSHING 10376-7 ITEM 7
18	TIE SHAFT AL 6061 .37 X 3.37
17	SCREWS WASHERS, LOCK
16	GUIDE-BOOM SCREEN
15	GEAR PIC DESIGN CORP. AB3- 100
14	SHAFT .125 DIA. X .50 LG SS 303
13	MOTOR ASSEMBLY-10376-11
12	BUSHING - 10376-21 ITEM 2
11	SHAFT .250 O.D. X 3.37 LG. SS 303
10	SIDE PLATE 10376-5
9	MOTOR ASSEMBLY 10376-6
8	SHAFT 10376-10 ITEM 2
7	GEAR PIC DESIGN CORP. G14-84
6	TIE ROD .43 DIA. X 3.37 LG.
5	SPRING BE-CU 5 TURNS 14 GA
4	SUPPORT ARM 10376-18
3	DRIVE ARM 10376-17
2	GEAR BOX & DRIVE ASSEMBLY 10375-10
1	REEL ASSEMBLY 10376-2



Note: For Clarity Near Side plate and side plate-reel Removed and shown in phantom.

Figure 14. Assembly - Deployment Mechanism

details, stronger and yet lighter, and that the boom attachment fittings could be greatly improved. Analysis of the size and shape revealed that the basic size should not be changed to any appreciable extent because of some unknowns in the packing density of the new screen configuration. The following major modifications were made to the design of the deployer:

a. The large idler gear alongside the reel was eliminated by relocating the roller drive motor and substituting a small spur gear.

b. Motor housings were designed to become structural members, attaching to both side plates.

c. An irregular pentagon shape was used to provide unobstructed access to the reel.

d. The reel design was changed from 42 pieces mechanically joined to an entirely-brazed assembly of 4 parts.

e. Movable parallelogram elements were stiffened and strengthened.

f. The boom guide was greatly simplified and lightened.

g. Aluminum was the primary structural material.

Table 6 summarizes the materials selected for use in the deployer to minimize the dipole moment and to be suitable for space application.

The design of the motor drive units was influenced by the necessity for motor selection prior to design of the remainder of the deployer and the very long lead times experienced in motor deliveries. The decision was made, therefore, to proceed with a modification of the basic design used for sealing the dc motors in the previous deployer. Full sealing of the motors was accomplished using o-ring and quad-ring seals of the materials listed in Table 7. Electrical connections were made through the housing via hermetic seals. Since the motors and reduction gears were certified to MIL-G-7118 lubrication was left intact.

Figures 11 through 16 show the deployer. Mechanism details are most clearly shown in Figures 15 and 16. Figure 15 shows the basic motor housings and the method whereby they contribute to the rigidity of the overall assembly. Figure 16, a direct view of the bottom of the assembly, clearly shows the direct drive details of the roller drive and its relationship to the movable guide mechanism for the boom.

All shafts, gears, and spacers were pinned, using taper pins lightly peened into place, for vibration proofing purposes. The nonmetallic gears were pinned and vibration proofed with an epoxy pin seal. Note, in Figure 16, two of the three side plate spacers. These were used for initial side plate alignment during assembly and for structural integrity. These supports were rigidized with shoulders and set screws. All set screws were locked in place by using nylon button inserts in the ends of the shafts.

Table 6. Deployment Mechanism Materials

Material	Use
Aluminum Alloy 6061-T6 with Alodine finish	Machined structural parts, reel, spacers, and covers.
Type 303 Stainless Steel	Precision shafts, taper pins, screws, clutch parts.
Type 304 Stainless Steel	Boom attachment tube and foil
Type 321 Stainless Steel	Boom guide
Aluminum Alloy 2024-T4 with Anodize finish	Small precision gears
Linen Phenolic, MIL-P-15035B Type FBE	Small nonmetallic gears
Phosphor Bronze	Lockwashers
Nylon	Shaft plus inserts for setscrews
Delrin AF	Bearings
Rubber Compound AMS3335	Quad ring motor shaft seal
Silicone, ASTM D735-58T TA-705BE$_1$B$_3$LF$_2$	Static O-rings
Adiprene - Formula "C"	Drive Rollers
Copper Beryllium Alloy 25	Springs
Yellow Brass	Clutch slide plate

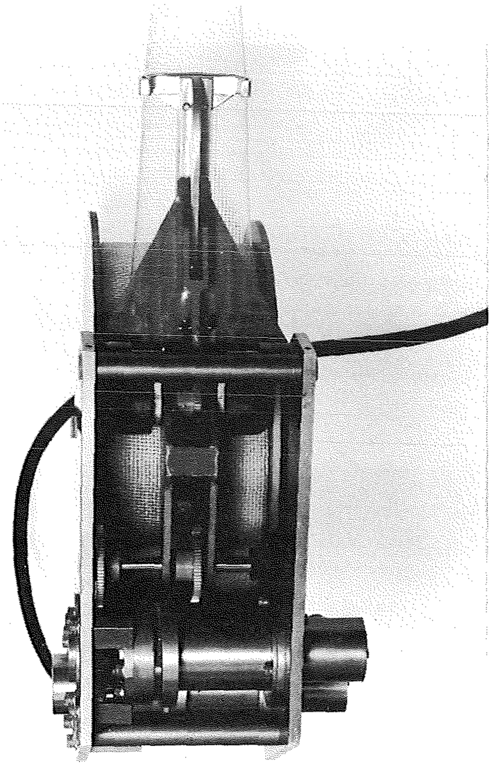


Figure 15. Deployment Mechanism Showing Motor Cases and Mountings

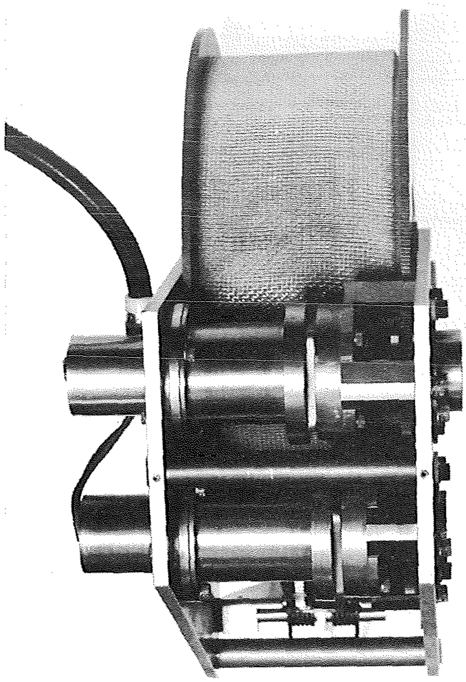


Figure 16. Bottom View of Deployment Mechanism Showing Roller Direct Drive Gear Train

All bearings were made from Delrin AF, an Acetal - Teflon combination. Appropriate clearnaces for these free-running bearings were required for operation under conditions of temperature and humidity. Use of this material permitted completely dry operation of the bearings without the need for lubrication of any sort.

The "Rubber" drive rollers were molded as follows:

<u>"C" Formula</u> - Shore A 72-76

Adiprene (Dupont) (Narmco 7343)	100 PBW
MOCA (Dupont) (Narmco 7139)	12 PBW
Monarch 74 (Cabot) Carbon Black	5 PBW

Carbon black milled into Adiprene with paint mill (2 passes)

Mold cure 30 minutes at 250° F in press.

This composition proved ideal for the application. Scuffing during operation was non-existant, and the required flexibility was evident at all operating temperatures.

2.3.1.1 Deployment Mechanism Operation. Operation of the deployment mechanism is relatively simple. The sequence is as follows:

a. Boom Deployment. The roller drive motor is energized in a CW direction transmitting power to the rollers. The rollers, which are spring loaded against the stored screen boom, push the screen from the reel. The reel is slightly restrained from free motion by the controlled friction of the slip clutch on the reel motor. During deployment the reel motor is not energized. A tight wind is therefore maintained during deployment.

b. Boom Rewind. Both motors are energized in a CCW direction. The powered reel winds the flattened boom while the powered rollers, operating at a constant speed, provide back tension on the rewound screen. The reel motor attempts to turn the reel at a faster rate than the rollers will permit. Differential motor speeds are compensated for by the slip clutch on the reel drive motor.

Reliable operation of the deployment mechanism is largely dependent upon the slip clutch operation. The clutch was designed using combinations of 303 stainless steel, brass, linen-phenolic gear, and a copper beryllium pressure spring. When properly adjusted, and initially broken in, the clutch maintained constant operating characteristics under all test conditions. Since the clutch adjustment controls the tightness of rewind, and also provides drag during deployment, too much clutch pressure will affect the deployment by overloading the roller drive motor and too little pressure will result in a loose reel wind.

Because of the motor operation sequence for deployment and rewind, a simple switching circuit was required. One was furnished with the delivery deployers. For demonstration, an unregulated 27-Vdc power supply was incorporated into this switching network. Inputs were provided for a regulated power supply.

2.3.2 TESTING AND EVALUATION. Deployment mechanism testing was conducted in accordance with Environmental Qualification and Acceptance Test Specification Number S2-0102, which was part of the contract. Component and assembly testing was conducted within the confines of the Process Development Laboratory, with the exception of the vibration tests that were conducted in the Convair division Vibration Laboratory. Temperature and vacuum tests were conducted routinely throughout the entire modification and assembly of the deployer. Final testing was conducted on the engineering test model, in toto.

Tables 7 through 9 summarize the tests conducted on the deployer and components. Figure 17 shows the deployer mounted on the test fixture for Z-Z axis vibration, while Figures 18 and 19 show the results of the entire sine and random vibration tests.

Table 7. Deployment Mechanism Environmental Tests

Test	Conditions	Remarks
Cold Storage	-30° C ± 2° C, 6 hours	Passed
Hot Storage	+60° C ± 2° C, 6 hours	Passed
Operational	-60° C ± 2° C, 1 hour	Passed
Operational	+70° C ± 2° C, 1 hour	Passed
Humidity	+30° C ± 3° C @ 90% relative humidity, 24 Hours	Passed
Leak Test	1×10^{-5} mm Hg	Motor hermetic seal Passed
Operational	1×10^{-5} mm Hg	Motor - passed (see text)

Table 8. Deployment Mechanism Sinusoidal Vibration Tests

Frequency (Hz)	Axis	Level (g 0-Peak)	Remarks
10 to 25	Thrust Z-Z	± 1.5	Passed
25 to 250		± 7.7	
250 to 400		± 12.3	
400 to 2000		± 5.0	
10 to 17	Lateral X-X and Y-Y	0.33 in. double ampl.	Passed
17 to 250		± 5.0	
250 to 400		± 10.0	
400 to 2000		± 5.0	

Table 9. Deployment Mechanism Random Excitation Tests

Frequency (Hz)	Acceleration (g-rms)	Test Duration	PSD Level (g^2/Hz)	Remarks
20 to 150	6.1	2 minutes per axis	0.01	Passed
150 to 300			Increasing from 150 Hz at a constant rate of +3.0 db per octave.	
300 to 2000				

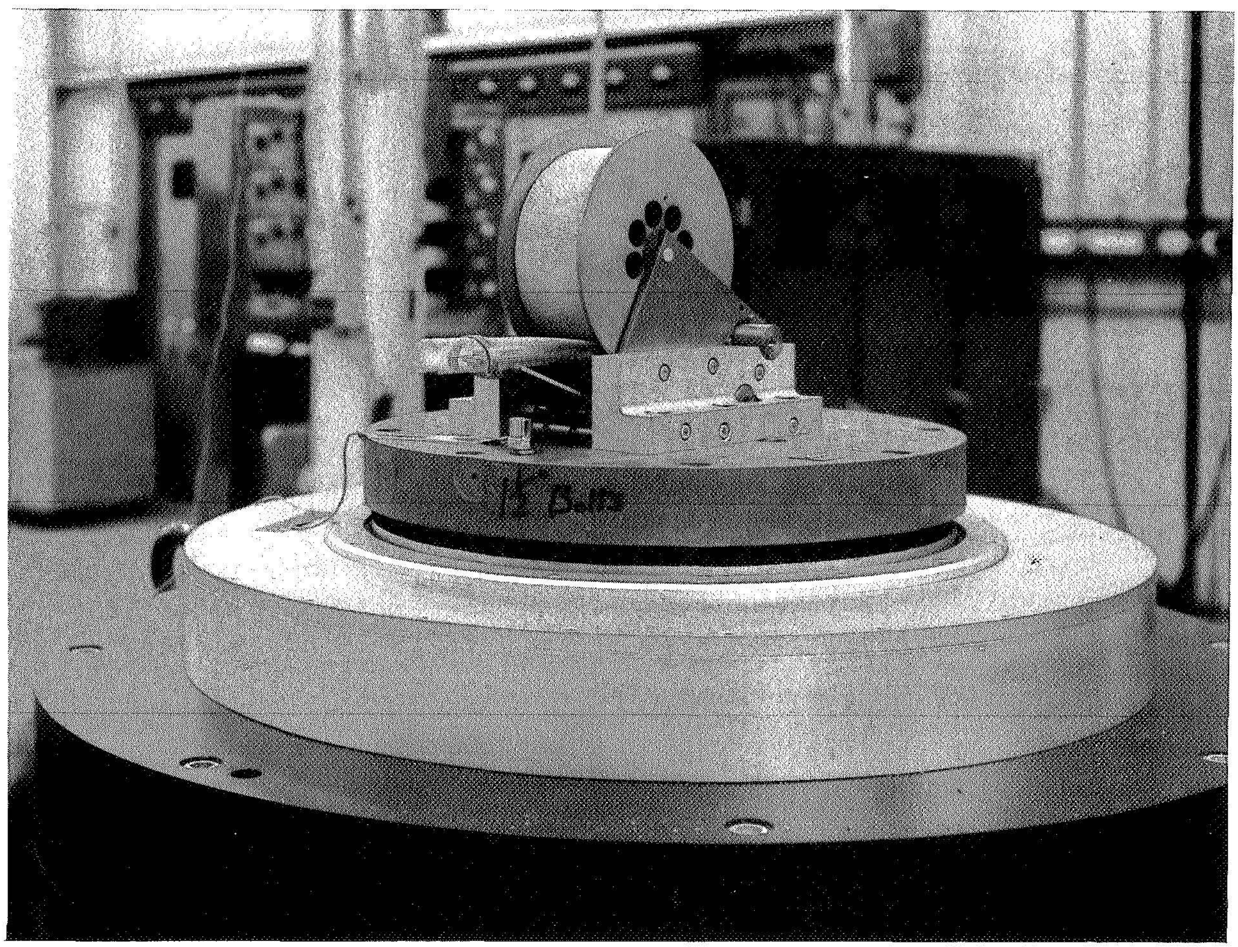


Figure 17. Z-Z Axis Vibration Test Showing Deployer Mounted on Test Fixture

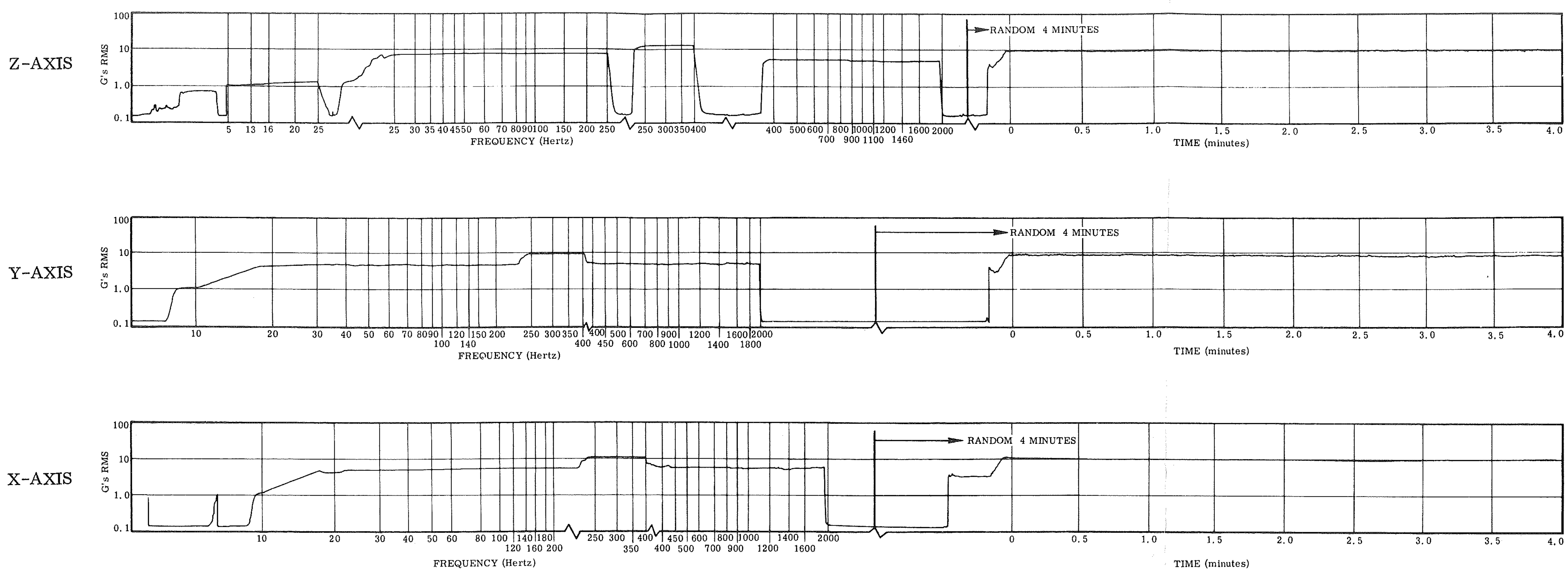


Figure 18. Reproduction of Sine Sanborn Recording, X, Y and Z Axes. Deployer Vibration Test.

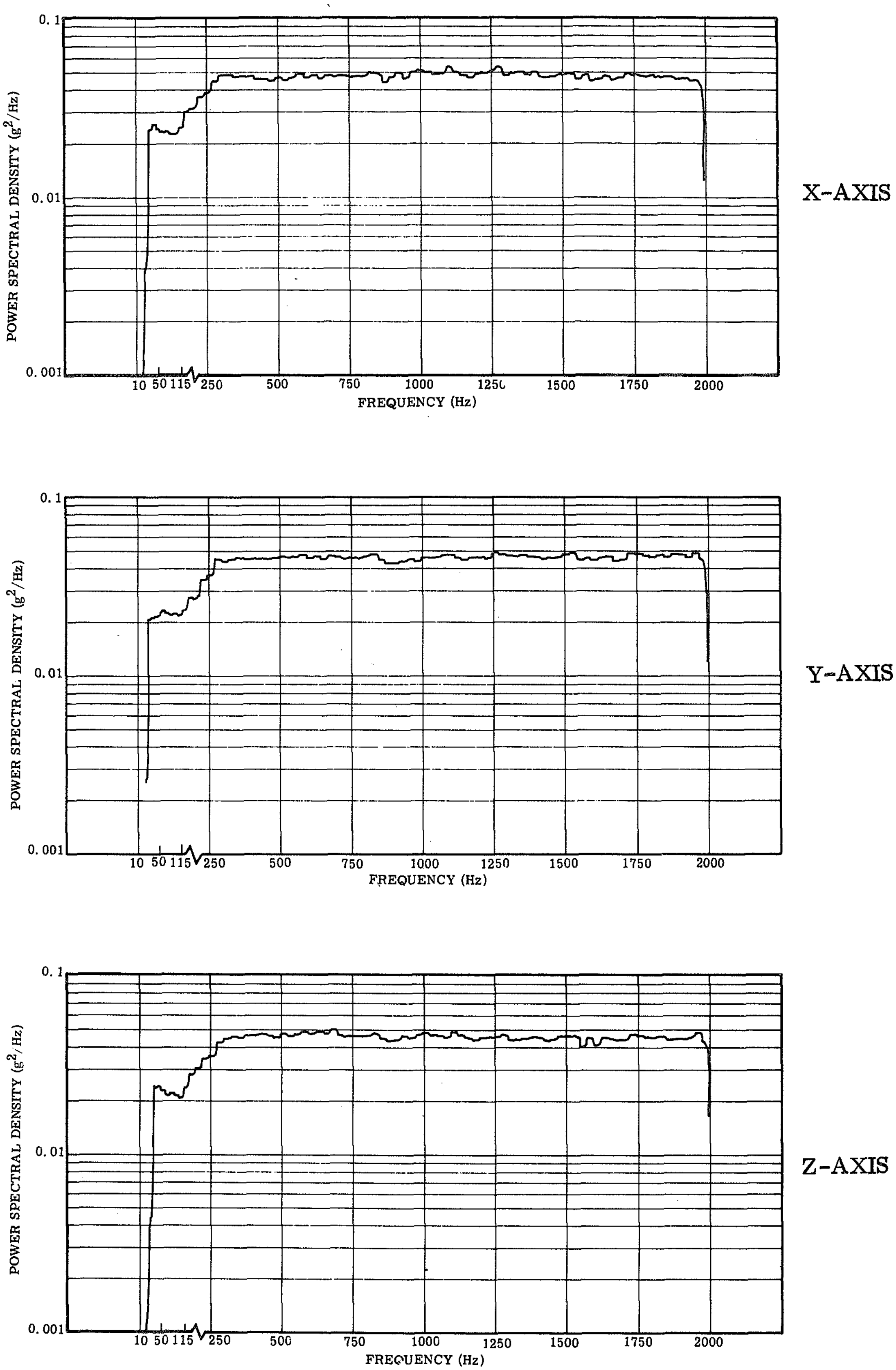


Figure 19. Power Spectral Density Versus Frequency

The temperature tests were considered to be the most critical portion of the testing. No problems were encountered in the elevated tests but modifications in the bearing clearances and some modifications in the shaft center-to-center distances were required in order to attain satisfactory operation at the sub-zero temperatures.

Vacuum testing was limited to the motor units alone. The hermetic seals for the electrical leads were mass spectrometer leak checked with helium. The motor assemblies were mounted in a special chamber. Electrical leads were brought out through hermetic seals, and provisions were incorporated to monitor the interior pressure while maintaining the casing under vacuum conditions. Cyclic operation of the motor was conducted under these conditions and the effectiveness of the quad-ring seal evaluated.

2.3.3 DELIVERED DEPLOYERS. Two deployment mechanisms, each loaded with 150 feet of wire screen boom, were delivered under the terms of the contract. Final mechanism characteristics after retrofitting of different motor gear ratios are given in Table 10.

Table 10. Deployment Mechanism Characteristics

Deployment Mechanism Characteristics	
Weight (bare)	3.88 lb
Weight (with 150 feet of screen boom)	6.0 lb
Dimensions, Maximum	4.75 × 8.81 × 4.87 inches (L × H × W)
Deployment Speed	0.44 ft/sec
Rewind Speed	0.46 ft/sec
Power Requirements at 27 Vdc	
Deployment	11.4 watts
Rewind	13.0 watts
Screen Boom Capacity	240 feet

SECTION 3

CONCLUSIONS AND RECOMMENDATIONS

The program for the refinement of gravity gradient booms and deployers was successfully accomplished with the delivery of three 150-foot booms, three booms each containing two splices, and two improved deployers. The purpose of this section is to discuss the pertinent areas, attempt an objective analysis of wire screen booms and deployers, and to recommend areas for potential improvement.

3.1 WIRE SCREEN BOOMS

The process of fabrication of wire screen booms was further developed and refined during the conduct of this program. The process was taken from one capable of producing limited lengths of less than 100 feet to one that was capable of single lengths in excess of 350 feet. In addition, the uniformity of the wire screen boom was markedly increased and the configuration more closely optimized. The overall performance of the boom was greatly improved through further refinements in the processing schedule.

Weaving of a more suitable wire mesh configuration was less of a problem area than had been anticipated. It was readily proved by the weaver that lengths of screen in excess of 575 feet could be woven to meet the minimum requirements of the wire screen boom concept. A higher degree of uniformity is desired, however. Weaving of screen for future applications would be expected to meet this aim since a major precedent was set by the successful weaving of long lengths, a highly questionable feat prior to its accomplishment.

Wire screen rigidizing equipment was modified to its limits. Reel-to-reel processing limits were established at 300 feet in continuous length without running risks in uniformity. The limitation of the reel-to-reel type of processing equipment developed and modified in this program and under NAS5-9597 occurs in the flux/alloy application step and, similarly, in the continuous brazing step. Flux thickness, resulting stacking density, and reel size forced this limit.

Continuous stretching of the Elgiloy-copper beryllium wire screen was attempted during the course of the program. It was not successful. Analysis of the method used, that of two different speed rolls, shows that the method was not carried far enough. Problems of feed and rewind from supply and take-up reels introduced waviness into a fully stretched screen. The magnitude of the problem forced the backup bulk stretching method to be used throughout the remainder of the processing phase. In spite of the obvious requirement of having a long length of unobstructed space to accomplish the gross stretching of an extended length of screen, the method is exceedingly valuable in producing a straight rigidized strand. Stretching introduces a measure of uncertainty into the production of long, single lengths of booms.

Random breaks in the screen lengths were experienced at stretch percentages sometimes far less than anticipated. In no case of the random breaks during stretching was a cause determined. Although individual sets of three warp wires in 36-inch lengths continuously tested at stretches of 35 to 40 percent prior to breaking, screen in bulk could not be trusted to withstand more than 25 percent. An analysis points to some minor variations in the continuous brazing portion of the process as being the primary cause. It was determined in NAS5-9597 that little or no tension on the Elgiloy warp during the brazing cycle was required. Brazing with desired tension levels was the sole cause of reducing the ductility of the Elgiloy to very low values (from 55% to less than 1% in some cases). Tension variations may well have been the cause of these random breaks during stretch.

The boom forming furnace and associated equipment proved to be highly reliable and capable of excellent uniformity.

Boom silver-plating was added to the overall process in order to reduce an apparent high absorptivity of wire screen configurations. It also served an esthetic purpose to give the screen a visual uniformity. The silver plating process was not optimized. Tests on the plating were not performed to determine the overall adhesion or uniformity of plate. Use and aging tests, however, showed that the plating process, as used, was apparently successful. No attempt was made to protect the silver-plated surface from atmospheric effects. The very nature of the open mesh configuration is conducive to bulk surface preparation or conditioning of tarnished silver wire surface. Liquid or gaseous cleaning of the affected surface can be done with the screen boom wound on a deployer reel just prior to use.

3.2 SPLICING

Three different methods of wire screen splicing were developed during the program. One of the methods was used to produce delivery test sections. Analysis of the splicing concept shows that techniques developed were highly successful. The splices produced in screen that was further processed into booms produced no deleterious effects on the boom or the splice area.

The three splice methods developed cover all cases of splicing other than actual formed boom joining. Wire-to-wire splices provided joining of raw screen to form unlimited single lengths and of rigidized screen to permit removal of defects in the processed screen or to effect repairs. A third method used a section of foil approximately one mesh in width to join dissimilar screens or separately processed sections.

Successful accomplishment of splicing and acceptance of the technique eliminates the two most costly and troublesome areas that potentially inhibit large or long-length boom use:

a. The need for weaving extra long screen sections.

b. The requirement for highly sophisticated equipment for processing unlimited lengths of screen.

3.3 DEPLOYMENT MECHANISM

Two improved deployment mechanisms, each loaded with 150 feet of wire screen boom were delivered to NASA GSFC. Both mechanisms were identical and represented a major modification of the design mechanism developed under NAS5-9597. The deployers met the requirements for launch and space environments.

The deployer design previously developed was modified in accordance with contract requirements. The relatively simple mechanism was further simplified by reducing the number of components, incorporating aluminum dip brazing for major assembly of the reel, and redesigning of the boom guide assembly. The deployer was constructed entirely of nonmagnetic materials. These materials, furthermore, were selected to be capable of withstanding a space environment. Weight was reduced from 7.0 pounds to 3.88 pounds, yet it was sturdy enough to pass vibration tests. In addition, the capacity of the reel was increased from 140 feet to 240 feet by modification of the roller drive assembly and, somewhat, by the increase in the stacking density of the screen boom. A positive boom guide design was incorporated to improve the action of the assembly. Motor cases were modified to markedly improve the sealing of the dc motors for vacuum use.

The deployer is oversize for a 150-foot capacity. This is due to the requirement for all modifications to be in work prior to processing of new mesh and new size wire screen boom. A 5-percent margin of safety for stacking density uncertainties plus the development of a method to increase the stacking density of the boom led to the overcapacity. Retrofitting of motor gear boxes was required to decrease the deployment speed to more realistic rates and to increase the drive motor torque values.

Modification of the design for reduced weight and increased vibration resistance provided for readily removable reels. The delivered deployers have this capability of rapid reel installation or change. The basic design of the deployers provides further capability for rapid modification to suit a particular application. Only minor changes would be required in the basic design to either increase or decrease the capacity or to minimize the volume and overall dimensions.

3.4 RECOMMENDATIONS FOR FUTURE WORK

The following recommendations are made for future studies and tests of the dual-material wire screen boom deployers.

a. Conduct a comprehensive evaluation of all splicing and screen joining techniques to include strength, thermal bending, and flexture testing, to permit the establishment of an optimum screen processing length, procedure, and equipment.

b. Conduct a comprehensive thermal deflection test program to determine the magnitude and direction of the deflection as a function of the irradiation angle with the boom seam.

c. Conduct a program of development to decrease the boom diameter from a nomimal 3/4 inch to 1/2 inch. Modify and construct a minimum size, minimum weight deployer for 150-feet of 1/2-inch boom.

d. Conduct an experimental program to determine the relationship of Elgiloy ductility (as measured by percent elongation), temperature, and load (stress). Incorporate the results of the findings into improved brazing and Elgiloy heat treatment processing for booms.

SECTION 4

NEW TECHNOLOGY

Two new techniques were developed to splice wire screen boom material to provide unlimited lengths of such material and to facilitate replacement of damaged or faulty screen. Both techniques provide for joining of wire screen material while leaving the physical properties of the material virtually unchanged.

4.1 WIRE-TO-WIRE SPLICE

The wire-to-wire splicing technique is used when joining wire screen with identical warp mesh. Splicing may be accomplished on raw screen or after the screen has been rigidized. Modified resistance welding technique and torch brazing are used to join individual pairs of overlapping wires. The joint provides no deleterious effects and the wire screen may be cleaned and processed in a normal manner.

Following is a step-by-step procedure of the wire-to-wire splicing process.

1. Trim screen ends to exactly 1/8 inch long.
2. Secure each end of screen in welding fixture using scribed lines as guides to ensure splice straightness and place matching wire ends side by side.
3. Resistance weld alternate wires, i.e., those warp wires that are passing underneath the closest shute wire.
4. Turn screen over and weld remaining wires.
5. Use established weld schedules.
6. Required tools and tooling aids are:

   3 to 10 by binocular magnifier
   Wood probe shaped to fit
   Assorted tweezers
   Sharp scissors

7. Inspect and clean weld area using MEK, acetone, or freon.
8. Brush-coat joint area and 1/2 inch either side with thinned Handy and Harman B-1 Flux.
9. Dry with IR heat source.
10. Remove dry flux film from between wires forming square with joints on two sides. Leave flux on wires. This step is only to remove excessive flux from the joint area. Use tapered, scribe-type tool.

11. Apply small dab of 50-50 flux-braze alloy (BAg-la) (-400 Mesh) to each weld splice joint.

12. Braze each joint individually using a Water Welder, No. 29 tip, 25 to 30 oz pressure.

13. Remove flux from joint area with hot water and short bristled brush (acid brush with bristles cut short).

14. Inspect and repair, if necessary.

4.2 BUFFER-STRIP SPLICE

The buffer-strip splice uses a narrow, 0.002-inch-thick strip of Beryllium Copper Alloy 25 foil as a buffer to join rigidized screens of unequal warp mesh sizes. This splice is performed only on fully rigidized wire screen material prior to boom forming. Resistance welding is used to tack the warp wires to the foil and silver brazing is used to effect the final joint.

Following is a step-by-step procedure of the buffer-strip splicing procedure.

1. Trim screen ends to 1/8 inch long, normal to screen length.
2. Secure the two screen ends in welding fixture butted against each other.
3. Place a 1/8-inch-wide strip of 0.002-inch-thick Beryllium Copper Alloy 25 under the joint.
4. Tack each wire in place with a resistance welder.
5. Apply a small amount of flux-braze alloy.
6. Braze each wire to wire joint and the wires to the foil.
7. Remove excess flux and trim excess foil.
8. Inspect and repair as necessary.

APPENDIX I

CONTRACT NAS5-10376 - WORK STATEMENT

CONTRACT SCHEDULE

ARTICLE I - STATEMENT OF WORK

A. Scope

The Contractor shall conduct a program for the refinement of the rigidized, woven screen gravity gradient boom and deployer previously developed under Contract NAS5-9597. This follow-on program is intended to provide longer booms, develop a boom joining technique, and provide improved deployers.

The program will consist of three phases:

1. Boom Development - The process for the making of booms shall be modified to permit the production of booms of extended length, as shall be demonstrated by the manufacture and delivery of three booms of 150' length. The booms shall be made of copper-beryllium and elgiloy mesh.

2. Boom Joining - A technique for joining or splicing of various lengths of the wire screen shall be developed. The technique, such as welding or brazing, shall unite the individual strands of wire such that the physical properties of the mesh are essentially unchanged.

   The joined material must be capable of withstanding successfully each of following tests which shall be conducted by the Contractor:

   a. Boom Stiffness - The boom material will not buckle or collapse upon the application of a one (1) ft-lb. bending moment during the simultaneous application of a torsional moment of not less than 0.005 ft-lb.

   b. Storage and Flexture Testing - The integrity of the wire joints and the effect of storage will be determined by preliminary testing. A finished screen of more than three feet in length will be rolled, restrained and stored on a suitable drum for one week in a laboratory atmosphere; it will be released and re-rolled at least five times and then stored for an additional week. This weekly testing and storage will be conducted for a period of one month or more. Examination of the wire joints and determination of straightness of the tube will be carried out each week.

The joined material must also be designed to withstand successfully each of the following tests which are not required to be conducted by the Contractor:

a. Boom straightness for booms up to 45 feet length -

   1) In a "zero-gravity" field with no sun, the best straight line drawn through the boom will not deviate from the required deployment direction by no more than 0.5 degrees.

   2) In a "zero-gravity" field with no sun, the actual boom center line will not deviate from the best straight line by more than 2 inches plus 0.1% of the length.

b. Storage Volume - The undeployed boom and its deployment mechanism will be capable of being stored in a volume of 0.5 cu. ft. plus 0.002 cu. ft. per ft. of length. Configuration of the storage volume will be that of a rectangular parallelepiped or of a right circular cylinder or similar suitable volume having a maximum dimension of five (5) feet.

c. Thermal deflection tests of 36-inch long specimens will be conducted only to provide data for use in verifying the mathematical model. Measure the deflection at a point 30 inches from the holding device.

d. Thermal Cycling - Specimens longer than 10 inches representing the finished wire mesh will be cycled at least six times between +300° F and -300° F at a heating rate or cooling rate of at least 10° F per minute while undergoing repeated flattening once per minute. The specimen will be examined for joint integrity and subsequently will be tested in tension to fracture at room temperature. Such tests will be applied to three specimens from each of the three selected mesh sizes.

3. Deployment Mechanism - Modifications to the design deployer delivered under Contract NAS5-9597 shall be undertaken such that the mechanism will survive a simulated launch environment, as for the ATS satellite.

The deployer design shall be modified, where necessary, to meet the temperature, humidity, and vacuum test specifications as for the ATS satellite, Specification S2-0102.

B. DELIVERABLE ITEMS

ITEM I - The Contractor shall deliver three (3) booms of 150' length as described in 1. above.

ITEM II - The Contractor shall deliver three (3) three-foot long boom specimens having "joints" at approximately 12 and 24 inches from the end.

ITEM III - The Contractor shall deliver two (2) deployers capable of meeting the ATS specification S2-0102, each to be loaded with a 150' boom.

APPENDIX II

WIRE SCREEN RIGIDIZING PROCESS

AND

CONTINUOUS BOOM FORMING

APPENDIX II

WIRE MESH SCREEN RIGIDIZING PROCESS AND CONTINUOUS BOOM FORMING

Wire screen rigidizing and tube forming processes were modified and refined over the procedures developed under Contract No. NAS5-9597. This is a complete process description as shown in the flow chart given in Figure II-1.

II.1 WIRE SCREEN PROCUREMENT

Wire screen was procured to the following Convair requirements:

Warp	Elgiloy, annealed 16 mesh 0.009-inch wire diameter
Shute	Beryllium Copper Alloy 25, annealed 22 mesh 0.007-inch wire diameter
Roll length	575 feet
Number of rolls	9
Spool	Convair-supplied, compatible with all equipment
Supplier	National Standard Co., Corbin, Kentucky

II.2 CLEANING

Manufacturing contaminants were removed from the as-received wire screen as follows:

a. Bulk clean in amyl acetate (lacquer thinner) for a 15 minute soak.

b. Bulk clean in an ultrasonic cleaning tank using Turco Caviclean No. 2, 1:20 ratio, at 160° F for 2 hours minimum.

c. Hot water rinse and forced convection dry at 220° F.

II.3 INSPECTION

Complete visual inspection of the wire screen is made to locate defects that are deleterious to the finished product. Examples of these are broken warp wires within the central 3-inch portion, extremely wide-spaced fill wires, and completely slack fill

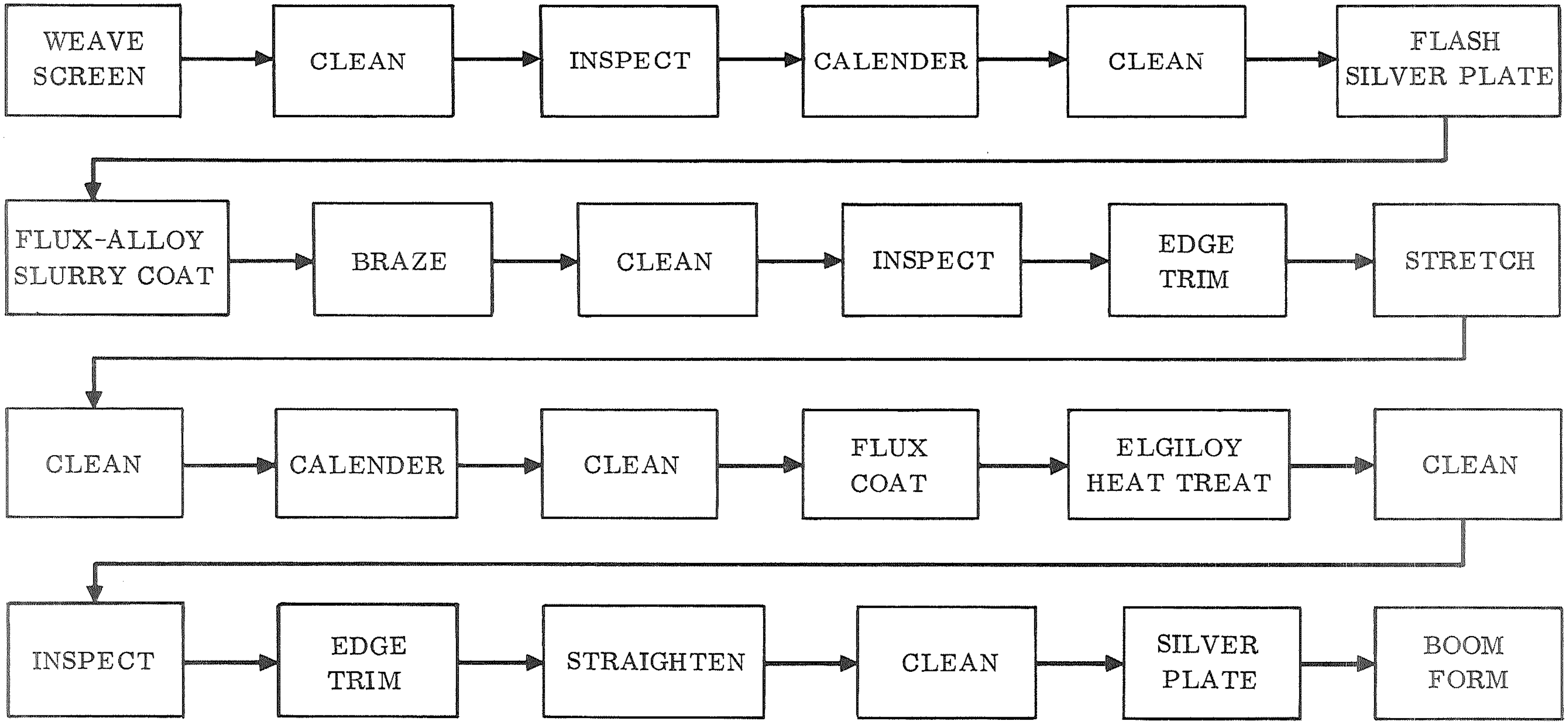


Figure II-1. Process Flow Chart

wires. All loose warp wires are also stripped from the roll at this step and cross slit warp wire ends trimmed to prevent possible unraveling.

II.4 CALENDERING

Continuous calendering is conducted on suitable rolls using a single pass schedule to reduce the measured wire cloth thickness to 12.5 mils.

II.5 CLEANING

Bulk cleaning of the calendered cloth is performed to permit plating. Soak cleaning in an ultrasonic tank using Turco Caviclean No. 2, 1:20 ratio, at 160° F for 2 hours minimum. The cloth is then thoroughly rinsed in hot and cold water using alternate submersion and drain techniques.

II.6 SILVER PLATING

Undried wire cloth is loaded into a continuous strand silver plating line for plating, double wash, tower oven drying, and rerolling.

Plating Solution

Silver Cyanide	4.0 av. oz./gal.
Potassium Cyanide	7.5 av. oz./gal.
Potassium Carbonate	6.0 av. oz./gal.
Temperature	78° F
Current Density	15 Amp./ft.^{2}
Voltage	3.5 Volts
Time	0.60 minutes in bath

II.7 FLUX ALLOY SLURRY COATING

Modified flux and braze alloy slurry coating is applied by continuous dipping and tower oven drying.

Slurry Composition

Handy and Harman B-1 Flux	100 lb
Sodium Flouride	15 lb
BAg-1a Braze Alloy, -400 mesh	2.40 lb av
Water	as required

II.8 BRAZING

Coated wire screen is brazed on a continuous basis at a speed of 2.5 ft/min. A vertical slot-type furnace operating at 1640° F yields a peak brazing temperature of the screen of 1280 to 1300° F.

II.9 POST-BRAZE CLEANING

Brazed wire screen is bulk cleaned to remove flux, by immersion in 145° F water. Subsequent hot and cold water rinses complete the cleaning. The cloth is forced-convection dried at 220° F.

II.10 INSPECTION AND EDGE TRIMMING

The brazed screen is thoroughly inspected to ensure a high level of braze quality throughout the subsequently processed screen. Non-continuous warp wires are trimmed from each edge of the screen to present a uniform end-to-end cross section for the next stretching operation.

II.11 ELGILOY COLD WORK

Elgiloy, or warp wire cold work is induced by gross stretching of the screen in the longitudinal direction. From 22 to 24 percent stretch is imparted at a rate of 1 percent per minute.

II.12 CLEANING

Contaminents and dirt particles are removed as in the cleaning cycle of II.2.

II.13 CALENDERING

A second calendering operation is performed to redistribute the crimp between warp and shute wires. A 12.5 mil final thickness is desired.

II.14 CLEANING

The cleaning procedure of 11.5 is repeated to prepare the screen for flux coating.

II.15 FLUX COATING

Flux coating is applied similar as in II.7. No brazing alloy is used in the make-up of the slurry,

II.16 ELGILOY HEAT TREATMENT

Step II.8 is repeated. The prime purpose of this step is the development of desired properties in the Elgiloy warp.

II.17 CLEANING

Step II.9 is repeated.

II.18 INSPECTION

Thorough inspection of the wire screen is conducted to ascertain the overall condition and to locate marginal braze areas (if any) and required trim-out areas.

II.19 TRIMMING

The rigidized wire screen is trimmed on both sides to 42 warp wires. The desired width is 2.52 to 2.54 inches. Results of the previous inspection are used to determine whether to favor one side or the other to eliminate defects.

II.20 STRAIGHTENING

Minor kinks are removed by gross stretching longitudinally. A 0.3 to 0.4 percent stretch is adequate.

II.21 CLEANING

The cleaning step given in step II.2 is repeated. The forced convection drying is eliminated. Further preparation for plating consists of immersion in 20 percent sulfuric acid at 78° F for 15 minutes, cold water rinse, immersion in 15 percent nitric acid at 78° F for 1 minute, and thorough water rinse.

II.22 SILVER PLATING

The silver plating step of II.6 is repeated using the following conditions:

Plating Solution	
Silver Cyanide	4.0 av. oz./gal.
Potassium Cyanide	9.0 av. oz./gal.
Potassium Carbonate	6.0 av. oz./gal.
Ammonium Thiosulfate (60%)	1/8 fl. oz. gal.
Temperature	78° F

Current Density	20 Amp/ft^2
Voltage	3.8 Volts
Time	0.80 minutes in bath

II.23 BOOM FORMING

Boom forming is accomplished using the automatic equipment developed and built for the purpose. Beryllium Copper Alloy 25 heat treatment is 60 minutes at 675° F under argon protective atmosphere. No post-heat-treatment cleaning is required.

APPENDIX III

WIRE SCREEN SPLICING PROCESS

APPENDIX III

WIRE SCREEN SPLICING PROCESS

Several wire screen splicing processes were developed. Following is the step-by-step procedure used to splice delivered booms.

1. Trim cloth ends to exactly 1/8 inch long.
2. Secure each end of cloth in welding fixture using scribed lines as guides to ensure splice straightness.
3. Resistance weld alternate wires, i.e., those warp wires that are passing underneath the closest shute wire.
4. Turn cloth over and weld remaining wires.
5. Use established weld schedules.
6. Required tools and tooling aids are:

   3 to 10 by binocular magnifier
   Wood probe shaped to fit
   Assorted tweezers
   Sharp scissors

7. Inspect and clean weld area using MEK, acetone, or freon.
8. Brush-coat joint area and 1/2 inch either side with thinned Handy and Harman B-1 Flux.
9. Dry with IR heat source.
10. Remove dry flux film from between wires forming square with joints on two sides. Leave flux on wires. This step is only to remove excessive flux from the joint area. Use tapered, scribe-type tool.
11. Apply small dab of 50-50 Flux-braze alloy (BAg-1a) (-400 mesh) to each weld splice joint.
12. Braze each joint individually using a Water Welder, No. 29 tip, 25 to 30 oz pressure.
13. Remove flux from joint area with hot water and short bristled brush (acid brush with bristles cut short).
14. Inspect and repair, if necessary.

GENERAL DYNAMICS

Convair Division